

Cristy, Gardiner, Reece & Weiss

Comparative Efficiencies of
Steam Engines and Steam
Turbines in small Units

Mechanical Engineering

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COMPARATIVE EFFICIENCIES OF STEAM ENGINES
AND STEAM TURBINES IN SMALL UNITS

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BY

HAROLD E. CRISTY
LION GARDINER
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THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE

IN MECHANICAL ENGINEERING

IN THE

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ENTITLED COMPARATIVE EFFICIENCIES OF STEAM ENGINES AND STEAM
TURBINES IN SMALL UNITS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF BACHELOR OF SCIENCE

A. F. Godeke

Instructor in Charge

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HEAD OF DEPARTMENT OF MECHANICAL ENGINEERING

OUTLINE.

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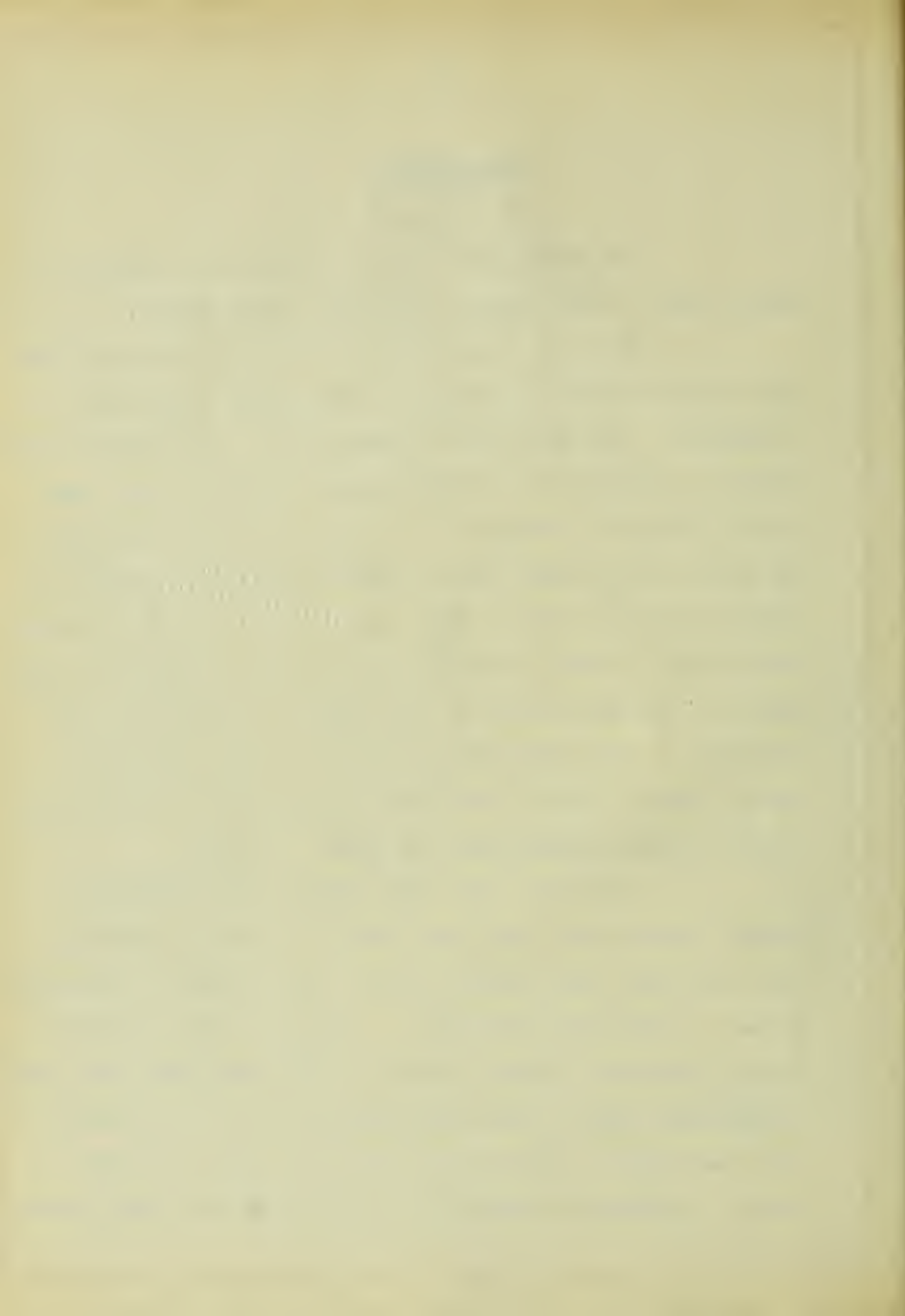
INTRODUCTION.

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The turbine is a machine by which the energy of a moving fluid is transformed, producing a rotary motion.

The first steam turbine of which we have any record was described by Hero, an Egyptian philosopher, in his book on "Pneumatics" written about 200 years B. C. He described this turbine as consisting of a hollow sphere rotating on two trunnions, through one of which it received steam from a generator. The sphere was provided with two hollow arms which projected in opposite directions and at right angles to the axis of the trunnions, each of these arms being furnished with a nozzle at right angles to its own axis and at right angles to the axis of the trunnions. The steam which entered the sphere through the hollow trunnion escaped from these nozzles, and the reaction due to this escaping steam caused the sphere to rotate.

It was not until 1884, however, when Charles A. Parsons invented his first steam turbine, a reaction turbine, that this great class of prime movers really began its phenomenal career of practical usefulness. Thus, the real development of the turbine has covered a space of only twenty-five years, and in that short time it has become recognized as the superior of the steam engine in many lines of work, the most noteworthy of which is probably the supplying of power to great electric power



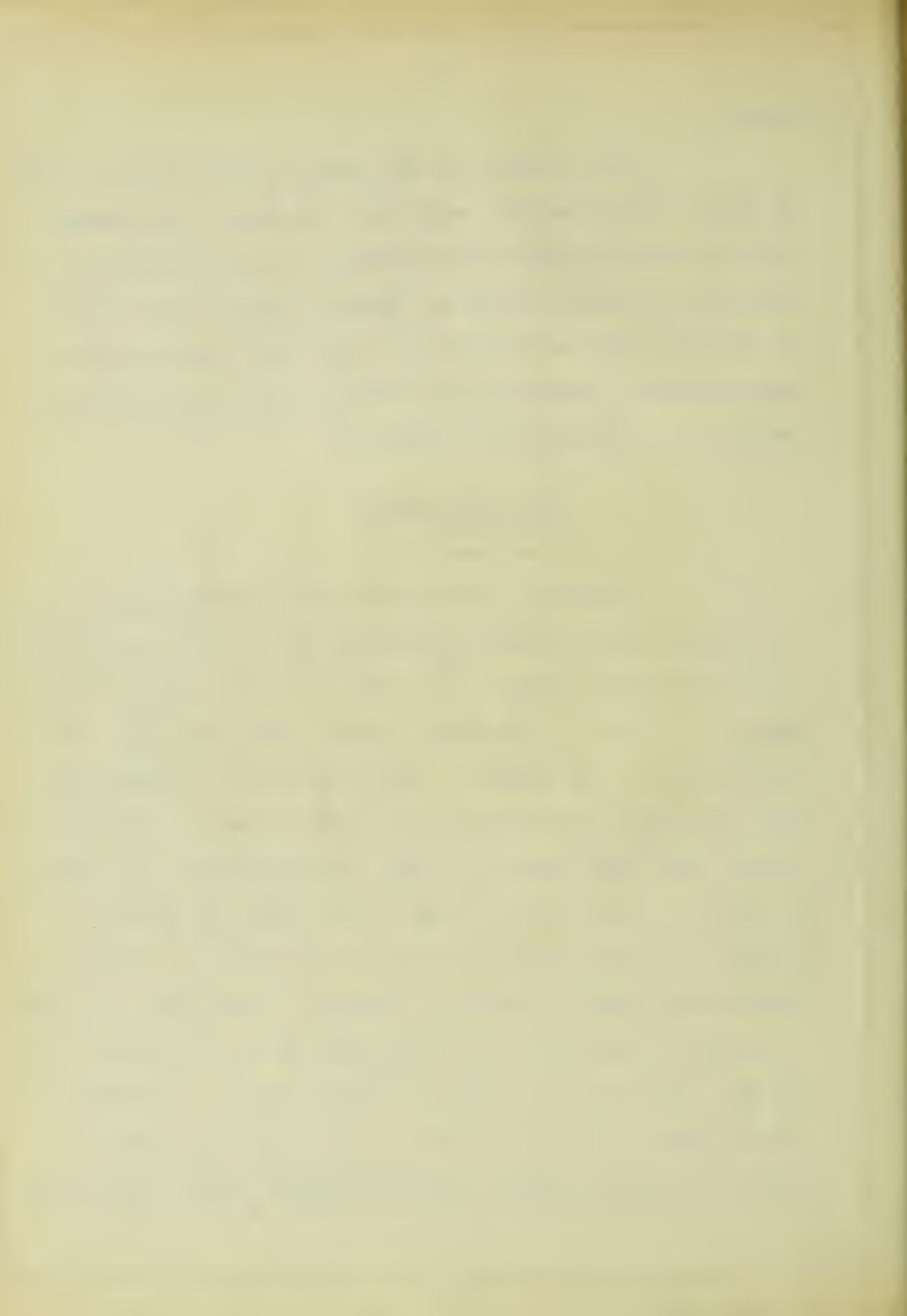
plants.

With reference to the form of energy which is used by them, turbines may be divided into two types;- the impulse turbine, which uses the velocity energy of the steam, and the reaction turbine which uses the pressure energy of the steam. Turbines may also be divided into single stage, and multiple stage turbines, depending upon whether or not the steam is expanded in one or many sets of nozzles.

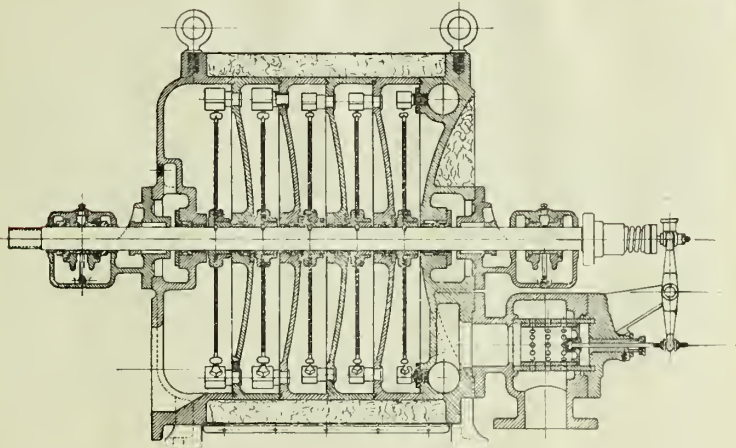
The Kerr Turbine.

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Considering the classifications named above the Kerr is a multiple stage, impulse turbine which utilizes the principle of the Pelton water wheel; jets of steam issuing from nozzles impinge on buckets in the turbine wheels and impart their velocity energy to the wheels. These buckets are of such shape that the direction of the steam is nearly reversed in passing through them, thus securing a very high efficiency in the transformation of the velocity energy of the steam into mechanical energy to be delivered at the shaft of the turbine. Bronze bushings are used to prevent the leakage of steam from one stage to another at the points where the shaft passes through the diaphragms and through the steam and exhaust ends. Reference to the sectional view of the turbine, Fig. 1 Pg. 3 will show, in addition to these bushings, packing glands for soft ring packing



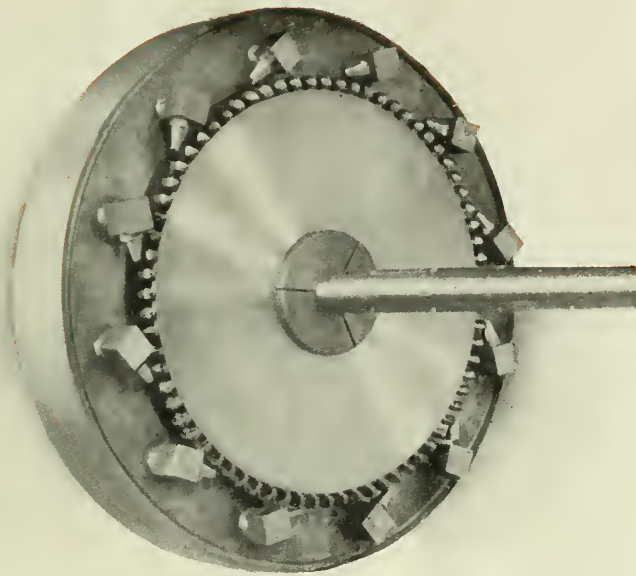
at the steam and exhaust ends. Between the soft packing glands and the metal glands is a chamber which receives the leakage from the metal glands and discharges it through a pipe connection to one of the low pressure stages of the turbine.



SECTIONAL VIEW OF KERR STEAM TURBINE.

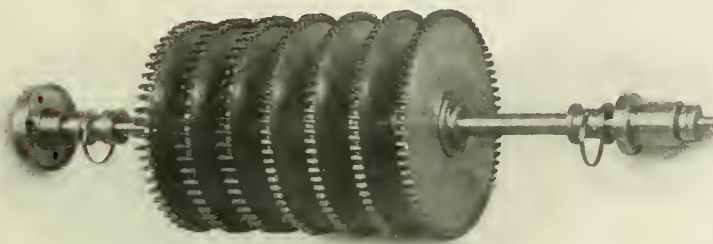
Fig. 1.





DISK OR BUCKET WHEEL AND NOZZLES.

Fig. 2.



COMPLETE ROTOR

Fig. 3.

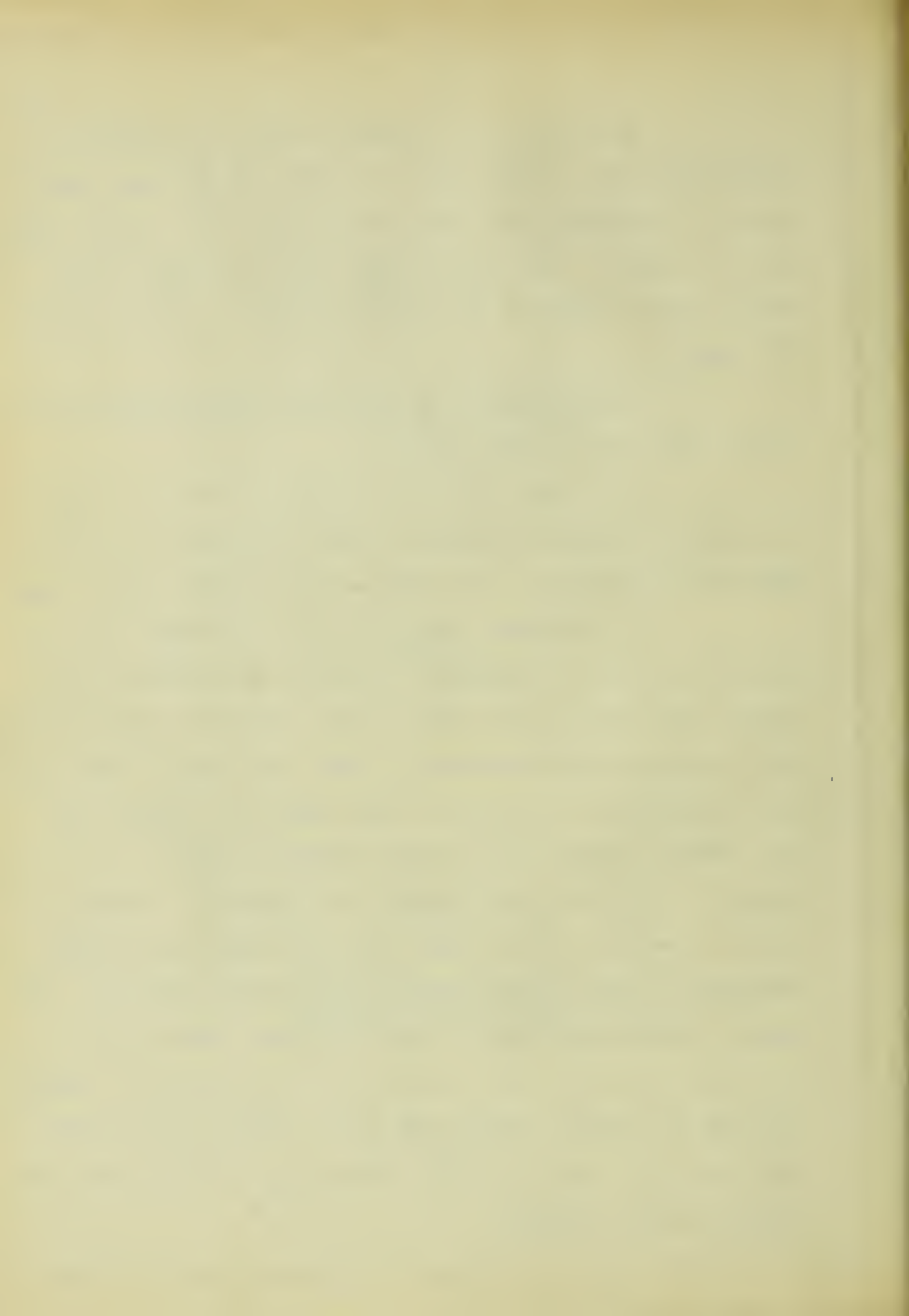
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The shell of the turbine is made up of two end castings and rings between which are diaphragm castings, which contain the nozzles, and divide the cylinder of the turbine into separate stages. The end castings carry the weight of the turbine and are provided with supports which are bolted to the bed plate.

The nozzles are screwed into a nozzle body which is riveted into the diaphragm casting.

The bucket wheels, one of which is shown in Fig.2 , are mounted on cast iron rings, and these are threaded on split hubs which are fitted to the shaft and held in place by pin keys.

The governor, which is of the centrifugal type, is mounted on the end of the shaft. The outward movement of the weights compresses a spring and operates a balanced piston valve, which throttles the steam supply. This throttling at light loads tends to superheat the steam and thus reduce the windage loss. The internal friction of a turbine depends so largely upon the quality of the steam that this throttling insures a minimum friction loss and thus, at light loads, the brake horse power increases at about the same rate as the pressure increases. The machine is lubricated by two ring-oiling, main bearings and a pivot block provided with a grease cup on the governor. Since there are no internal rubbing parts, the exhaust steam is free from oil, and so may be used for any purpose to which clean, low pressure steam is adapted.



The Kerr turbine is adapted to driving high- speed machines, such as electric generators, centrifugal pumps, and pressure blowers, direct connected. One great advantage of it is that it can attain full speed from a stand still in less than ten seconds. If necessary it may be started with full steam pressure admitted to the cold turbine without danger.

Purpose of Tests.

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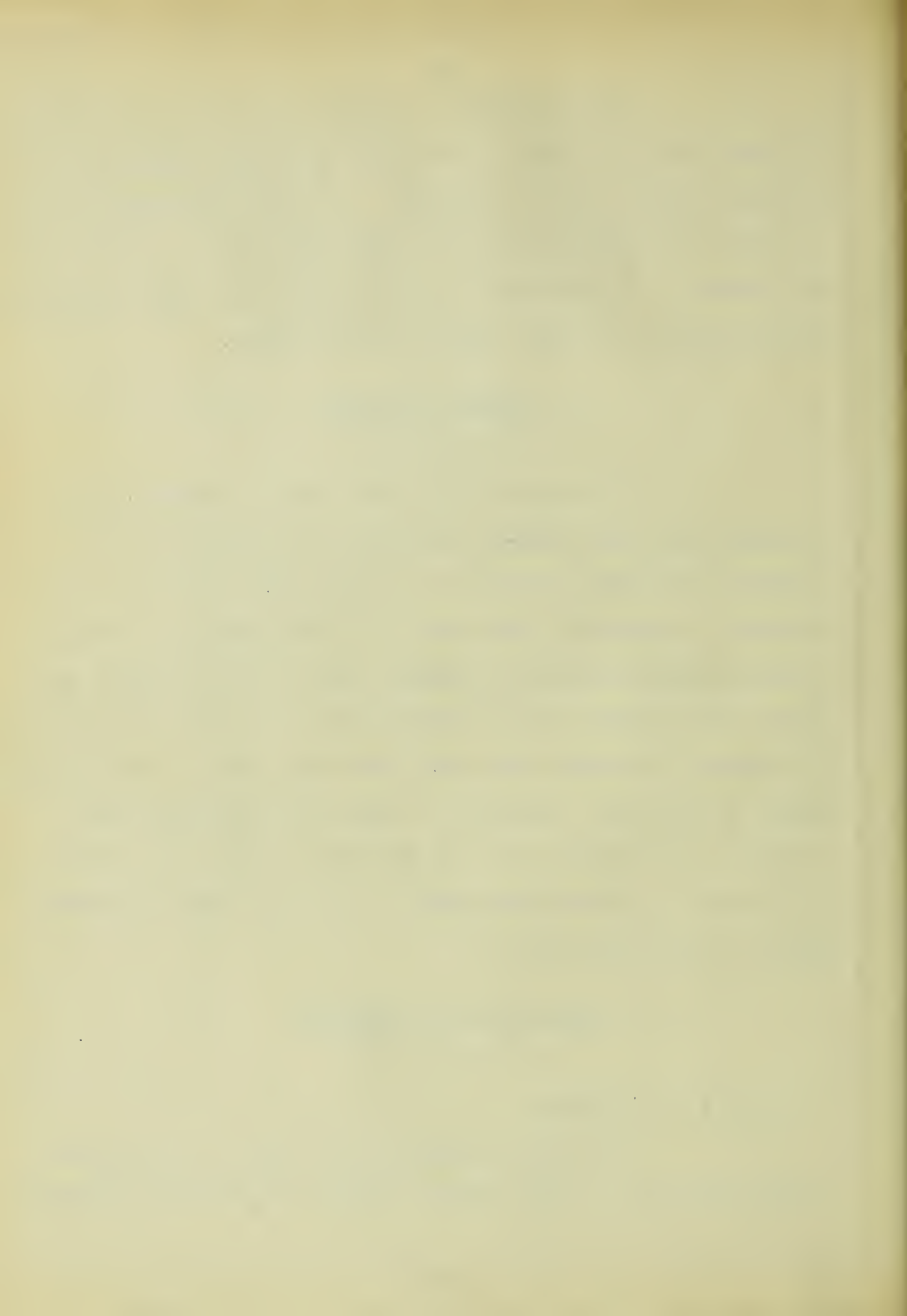
The purpose of the tests herein described was to determine the steam economy, the thermal efficiency, and the potential efficiency of the 60 H. P. Kerr steam turbine in the Mechanical Engineering Laboratory at the University of Illinois running noncondensing with saturated steam at loads varying from zero to the maximum, at the following steam pressures; 100 pounds, 115 pounds, 130 pounds, 140 pounds, and 150 pounds. The ultimate object in view was a comparison of the efficiencies and steam economy of this turbine with the efficiencies and steam economy of the 60 H. P. Ideal steam engine in the same laboratory running under the same conditions.

Description of Apparatus.

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(1.) The Turbine.

The turbine tested is an 18 inch, 6 stage, impulse turbine built by the Kerr Turbine Company of Wellsville, New York.



It is rated as a 60 B. H. P. machine running noncondensing on saturated steam at 150 pounds pressure. A general view of the turbine is shown in Fig. 4 Pg. 8.

(2.) Auxillary Apparatus.

The steam was condensed at atmospheric pressure, for the purpose of weighing, by a Wheeler Surface Condenser, manufactured by the Wheeler Condenser and Engineering Company, of New York. The capacity of the condenser is 60 H. P. and it contains 225 sq. ft. of cooling surface. The cooling water is circulated by a steam pump on the condenser. Leakage tests showed that when the turbine was not running no water was discharged by the air pump, though the air and circulating pumps continued to run, thus proving that there was no condenser leakage.

A Prony brake, brake standard, and platform scales were used in determining the B. H. P., and platform scales were also used for weighing the condensed steam from the condenser. These scales were calibrated by comparison with standard test weights.

(3.) Instruments.

The following testing instruments were used:-

Pressure Gages.

Thermometers.

Throttling Calorimeter.

Speed Counter.

All pressure gages and thermometers used were cal-



8.

ibrated by standard methods, calibration curves were plotted for each, and the readings taken were corrected accordingly.

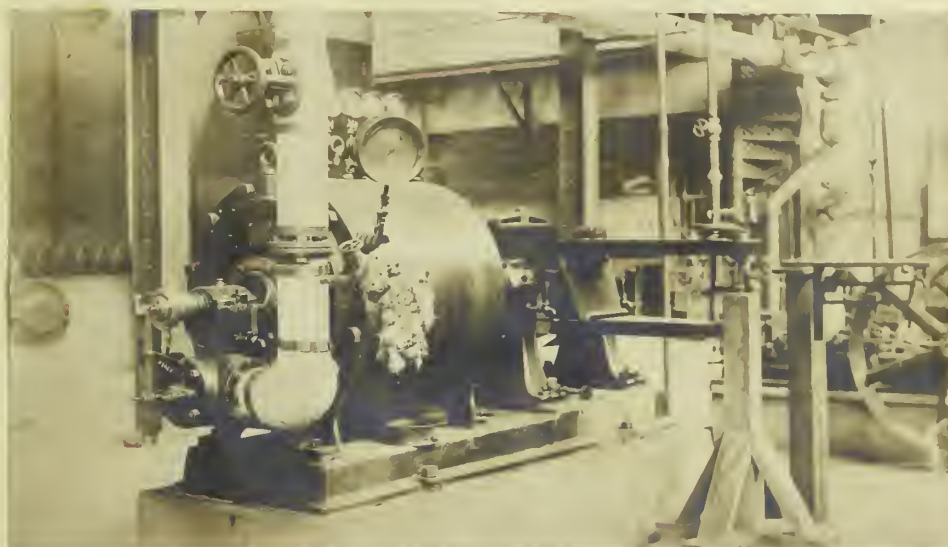


Fig. 4.



Method of Conducting Tests.

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As stated above, tests were made at the following steam pressures: 100 pounds, 115 pounds, 130 pounds, 140 pounds, and 150 pounds. At each of these pressures tests were made, in so far as was possible, at zero load, one-fourth load, one-half load, three-fourths load and full load. With one exception, - zero load at 115 pounds, - all tests were conducted for somewhat more than an hour, and readings were taken at five minute intervals. From each test made the thirteen consecutive readings which proved to be the most uniform in all respects were selected as furnishing reliable data for one hour run. Thus it appears that all conclusions are arrived at from a series of tests of only one^{hour} each, though in reality many of the tests lasted for two hours or more.

The following readings were taken by three observers:

Wt. of Condensed Steam.

Revolutions per Minute.

Steam Main Pressure.

Steam Pressure in each Stage.

Calorimeter Temperature.

Exhaust Temperature.

Engine Room Temperature.

External Air Temperature.

Barometer.

All readings were corrected from calibration curves before being transferred to data sheets.

CALCULATION OF DATA.

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The following data were calculated for each test separately.

1. Brake Horse Power.
2. Quality of Steam Entering.
3. Steam Consumption per B. H. P. per hour.
4. Thermal Efficiency.
5. Potential Efficiency.

Sample calculation for the full load test using 150 pounds steam pressure in the main.

(1.) For brake horse power.

$$\text{B. H. P.} = \frac{2\pi R N W.}{33000}$$

Where R = the length of the brake arm in feet = 2.5 ft.

W = the net weight on the brake scales in pounds = 35.0

N = average R. P. M. of brake pulley = 3591.

$$\text{B. H. P.} = \frac{2 \times 3.142 \times 2.5 \times 3591 \times 35}{33000} = 58.70$$

(2.) For average quality of steam.

$$x = \frac{q_1 - r_1 - C_p(T_s - T_a) - q}{r}$$

Where x = quality of entering steam.

q = heat required to raise the temperature of the water from 32°F. to the temperature corresponding to the pressure of the entering steam = 337.14

q_1 = heat required to raise the temperature of the water from 32°F. to the boiling point corresponding to the atmospheric pressure. = 180.04

r = total heat of vaporization from and at the temperature corresponding to the pressure of the entering steam. = 856.30

r_1 = total heat of vaporization from and at the temperature corresponding to the atmospheric pressure = 966.42

C_p = specific heat of steam at constant pressure. = 0.48

T_s = temperature of steam in calorimeter = 269.

T_a = temperature of steam from steam tables corresponding to atmospheric pressure. = 211.6

$$x = \frac{180.04 + 966.42 + .48(269 - 211.6) - 337.14}{856.30} = .977$$

(3.) For steam consumption per B. H. P. per hour.

$$W = \frac{x w}{\text{B. H. P.}}$$

Where x = the average quality of the steam = .977

w = total weight of steam used per hour. = 2439 pounds.

W = the weight of dry steam used per B. H. P. per hour.

$$W = \frac{2439 \times .977}{58.7} = 40.76 \text{ pounds.}$$

Since there is considerable difference of opinion as to the definitions of thermal efficiency and potential efficiency we will give these definitions as interpreted for use in this

thesis.

Thermal efficiency is the ratio of the heat equivalent of the work delivered by the machine to the difference between the heat above 32° furnished by the steam and the heat above 32° in the condensed steam.

Potential efficiency is the ratio of the heat equivalent of the work delivered by the machine to the heat which it would consume by adiabatic expansion of the steam actually used.

$$E_t = \frac{2545}{W (H_1 - q)}$$

$$E_p = \frac{2545}{(H_1 - H_2)W}$$

Where E_t = thermal efficiency.

E_p = potential efficiency.

q = heat above 32° in one pound of condensed steam at atmospheric pressure.

H_1 = total heat of one pound of the entering steam quality considered.

H_2 = total heat in one pound of the same steam after adiabatic expansion to atmospheric pressure.

W = weight of moist steam used per B. H. P. per hour.

$$E_t = \frac{2545}{(1177.17 - 180.04) \times 41.55} = .052$$

$$E_p = \frac{2545}{(1177 - 1020) \times 41.55} = .398$$

CURVES.

-----6-----

On pages 20 to 24 , inclusive, are curves showing steam pressure in the different stages of the turbine for the various loads at each steam main pressure used on this series of tests. The curves themselves have no value except in so far as their smoothness indicates good design.

Reference to the points on the curves will show that if absolute pressures are considered, the pressure in the stage nearer the exhaust of any two successive stages never falls below 57 percent of the pressure in the preceeding stage. This indicates that diverging nozzles between the successive stages are not necessary, since it has been demonstrated by experiment that the maximum pressure drop through the ordinary nozzle is 43 percent.

On pages 25 to 29 , inclusive, are curves showing the relation between the B. H. P. and the steam consumption in pounds per B. H. P. per hour. It will be seen that for $1/4$ load and $1/2$ load the steam consumption does not vary much with the pressure, but that for the greater loads the trend of the curves shows a reduction of steam consumption for the higher pressures, as should be expected. It should be noted, also , that for the greater loads at a given pressure the steam consumption changes but very little with the load.

On pages 30 to 34 , inclusive, are curves showing the variation of the thermal efficiency with the B. H. P. for the

different steam pressures. They indicate that the efficiency is greater for the higher pressures, as should be expected. They indicate, also, that the efficiency is a maximum at about 50 B. H. P.

On pages 35 to 39 , inclusive, are curves showing the variation of the potential efficiency with the B. H. P. for the different steam pressures. These curves show greater efficiencies for the higher steam pressures when we consider the greater loads, but they show that for smaller loads the reverse is true. They also show that the maximum efficiency is reached at from 50 to 60 B. H. P., and occurs at smaller loads for the lower steam pressures than for the higher. The maximum efficiency is attained at 58.7 H.P. and 150 pounds pressure.

CONCLUSION AS TO TURBINE.

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This turbine was rated by the manufactures as 60 B. H. P. running noncondensing at 150 pounds steam pressure. It was rated, moreover, to give a steam economy, under these conditions, of 34 pounds per B. H. P. per hour running at full load and 44.5 pounds per B. H. P. per hour running at one-fourth load, and also, to give a potential efficiency of 35 percent at full load. In addition to this the manufacturers send out a curve showing a point at 1/4 load for this machine.

As shown by the accompanying series of tests, the turbine does not come up to its rating, either with regard to

power developed or with regard to steam economy. Its potential efficiency, however, is greater than that at which it was rated. The maximum B. H. P. developed was 58 percent; the steam consumption at this load was 40.7 pounds per B. H. P. and ^{one} at a fourth load was 66.5 pounds per B. H. P.; and the potential efficiency was 39.8 percent. The economy is fair for a unit of this size. Moreover, for such a unit reliability is of greater importance than economy, and in this respect the Kerr turbine is very good. It has very few parts to wear out, and requires very little attention after the oil reservoirs are filled.

It will be noticed that no zero load tests were made for pressures above 115 pounds. The reason for this was that the governor could not be set to keep the speed below 3800 R. P. M.; the rated speed is 3600 R. P. M., and for speeds greater than 3800 R. P. M. the governor became overheated. This feature shows faulty design.

The reason that the rated B. H. P. could not be developed is probably due to the fact ^{that} the rating was based on a wrong assumption by the manufacturers. In their rating of 60 B. H. P. at 150 pounds steam pressure they considered that this pressure was to occur in the chamber for the entering steam, rather than in the main steam line where pressure for rating basis is ordinarily taken.

COMPARISON OF THE TURBINE WITH A 60 H.P. IDEAL HIGH SPEED ENGINE.

-----C-----

Description of Engine.

The engine with which comparison is made is rated to deliver 60 B. H. P. running noncondensing on 150 pounds steam pressure at 300 R. P. M. It is a double-acting, slide-valve engine, equipped with an inertia governor. The series of tests of this engine, which furnished the data for comparison of its operation with the operation of the turbine, was made by L. Gardiner and W. W. Reece, both U. of I. '09, and constituted their thesis for the degree of B. S. For a complete description of the engine, and discussion of the method of testing and data and curves obtained their thesis, which bears the same title as this , should be consulted.

Comparison of results obtained from turbine and engine as shown by curves for steam consumption, potential efficiency, and thermal efficiency.

(1.) Steam Consumption.

On pages 25 to 29 , inclusive, are curves showing the steam consumption of the engine at different loads and pressures to the same ordinates as the corresponding curves for the turbine. These curves show that in the turbine the steam consumption for any given load does not vary much with the pressure. But in the case of the engine the consumption is a

minimum at 115 pounds pressure, and increases as the pressure increases above this value. This state of affairs should not exist, and the probable explanation for it is leaky valves.

For the lighter loads the turbine has a decided advantage over the engine in its steam consumption. This advantage grows less, however, as the loads increase, and the general trend of the curves indicates that the steam consumption would be the same for the two machines at about 75 B. H. P. if the turbine were capable of delivering that amount of power.

(2.) Thermal Efficiency.

The thermal efficiency of the turbine for any given load does not vary much with changes of steam pressure. It increases, however, with increase in load.

The thermal efficiency of the engine at low loads is higher at a given load for the lower steam pressures. At 40 B. H. P. the efficiency is about the same for all pressures. At loads greater than 40 B. H. P. the thermal efficiency is higher for the higher pressures.

The difference between the thermal efficiency of the turbine and that of the engine decreases at all pressures as the load increases. At 60 B. H. P. the efficiencies of the two machines are about the same.

(3.) Potential Efficiency.

The potential efficiency of the turbine is higher

at low load for the lower steam pressures than for high steam pressures. At 45 B. H. P. the efficiency is about the same for all pressures. At loads greater than 45 B. H. P. the efficiency for any given load is higher at the higher pressures.

The same is true with respect to the potential efficiency of the engine, except that it is about the same for all pressures at 60 B. H. P. instead of at 45 B. H. P. as in the case of the turbine.

The difference between the potential efficiency of the turbine and that of the engine increases at all pressures as the load increases, and the advantage in every instance is in favor of the turbine.

ULTIMATE CONCLUSION FROM COMPARISON.

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It is clear from the above discussion that from the stand point of economy in operation the steam turbine is the superior of the steam engine. Moreover the turbine possesses the additional advantage of requiring smaller floor space and less expensive foundation. The single advantage of the engine over the turbine, as indicated by these tests, lies in the fact that the engine was capable of developing 1/4 overload, while the turbine could hardly be made to develop its rated full load, which fact is easily explained by ^{the} faulty basis that the turbine manufacturers worked upon in assuming the specified steam pressure

to obtain in the chamber of the entering steam rather than in the main steam line.

References:-

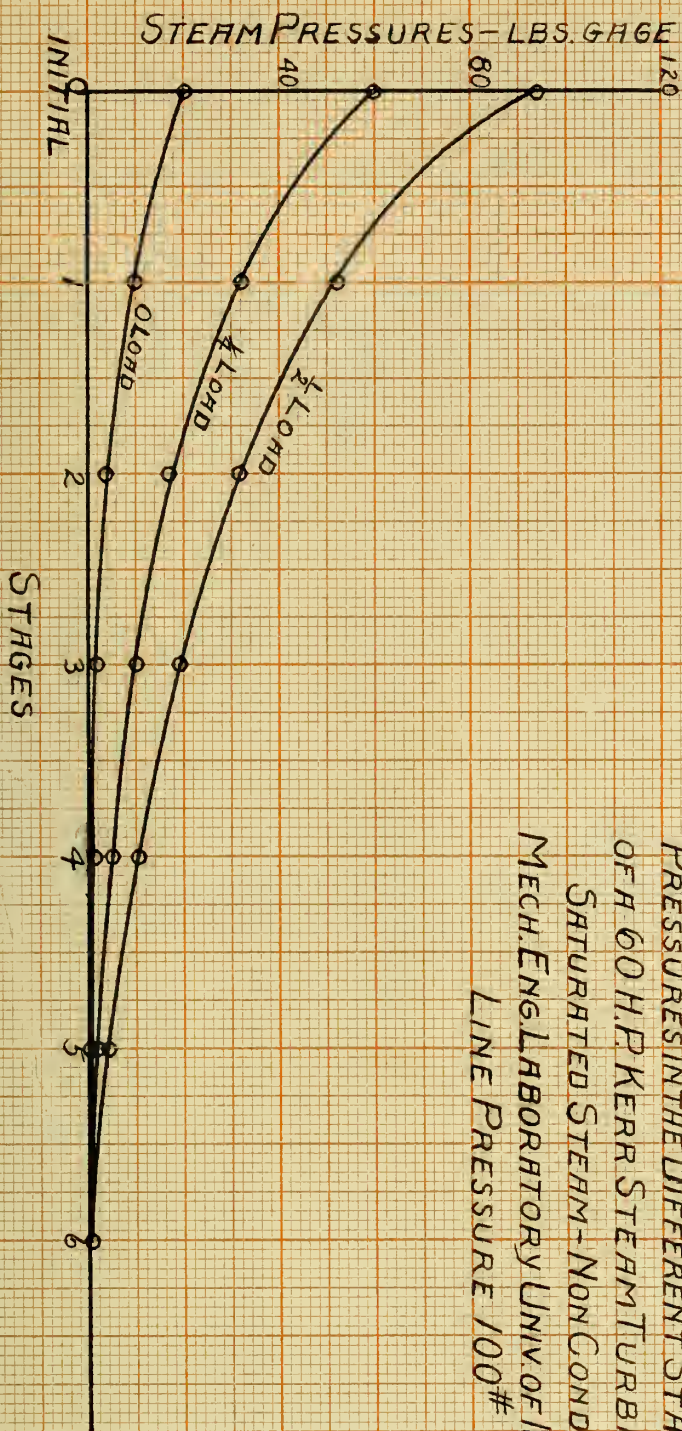
Thesis of L. Gardiner and W. W. Reece of U. of I.
'09, for degree of B. S. in M. E.

"Steam Turbines, "(pp. 93 - 94), by Thomas.

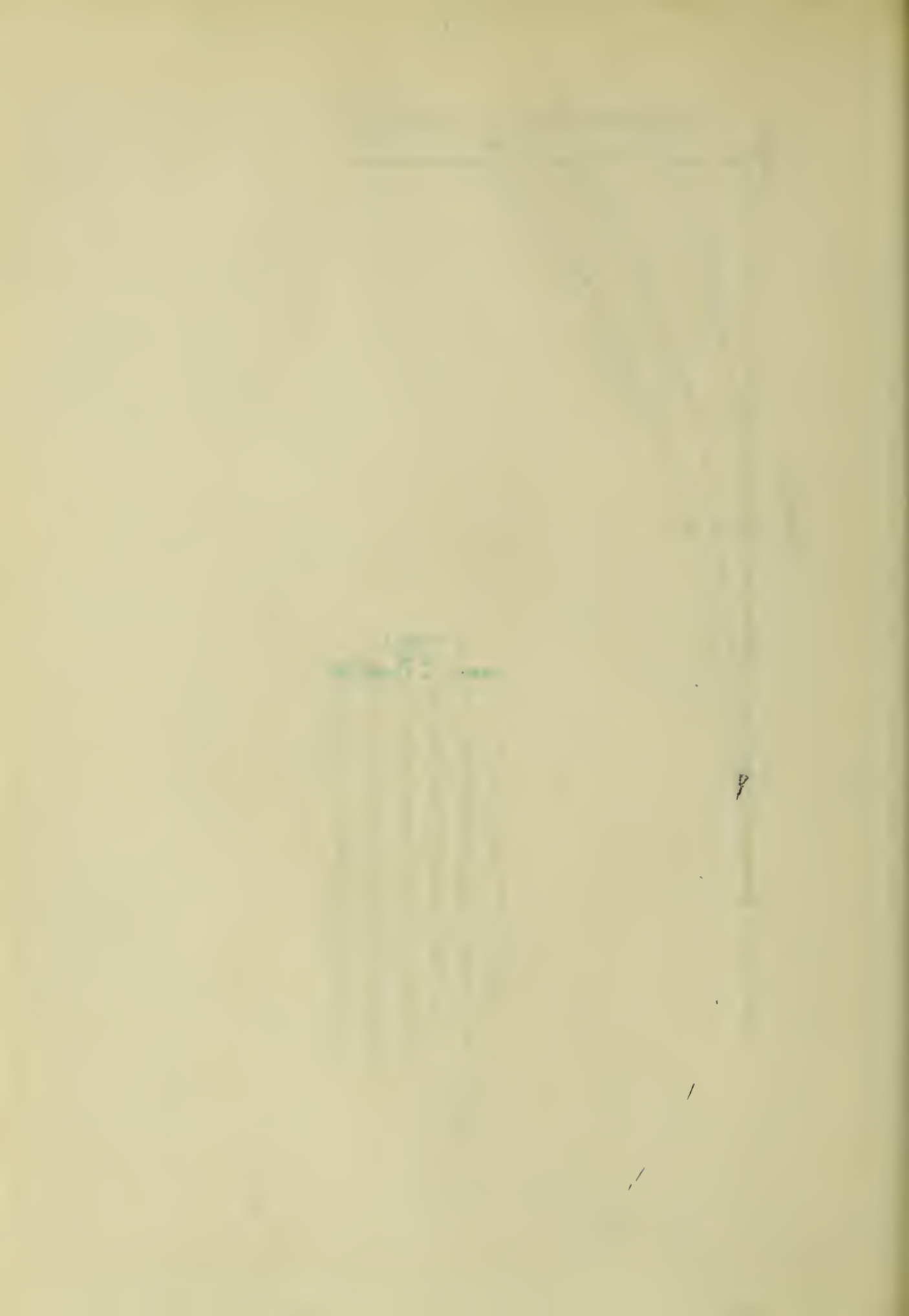
Power,- Feb., 1905,- " Kerr Compound Steam Turbine."

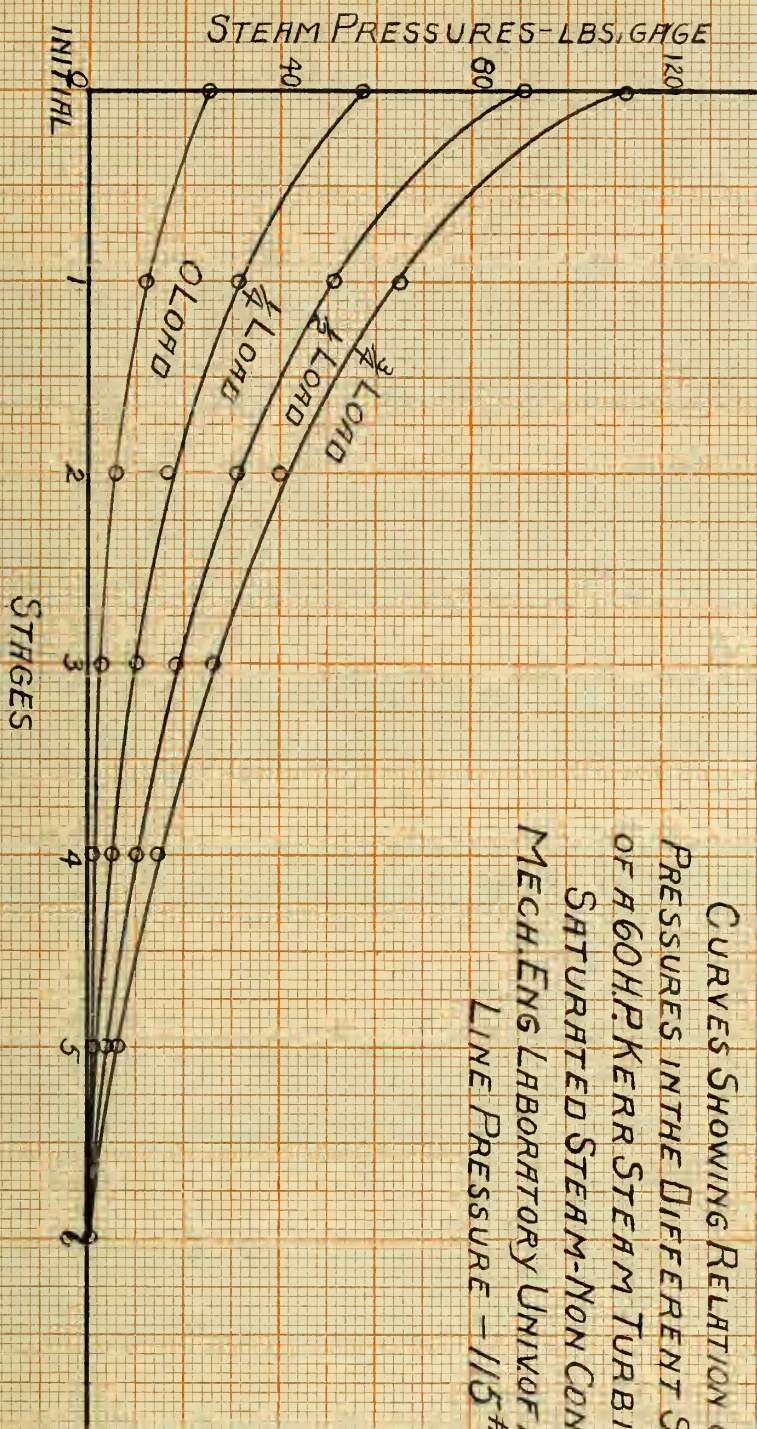
American Machinest,- Jan. 18, 1906,- " The Kerr
Steam Turbine."

The Engineer,- Jan. 1, 1908,- "The Kerr Steam
Turbine."



CURVES SHOWING RELATION OF
PRESSURES IN THE DIFFERENT STAGES
OF A 60 H.P. KERR STEAM TURBINE
SATURATED STEAM - NON COND.
MECH. ENGL. LABORATORY UNIV. OF ILL. '08-'09
LINE PRESSURE 100 #





CURVES SHOWING RELATION OF
PRESSURES IN THE DIFFERENT STAGES
OF A 60 H.P. KERR STEAM TURBINE
SATURATED STEAM-NON COND.
MECH. ENG. LABORATORY, UNIVERSITY OF ILL. 08-09
LINE PRESSURE - 115 #



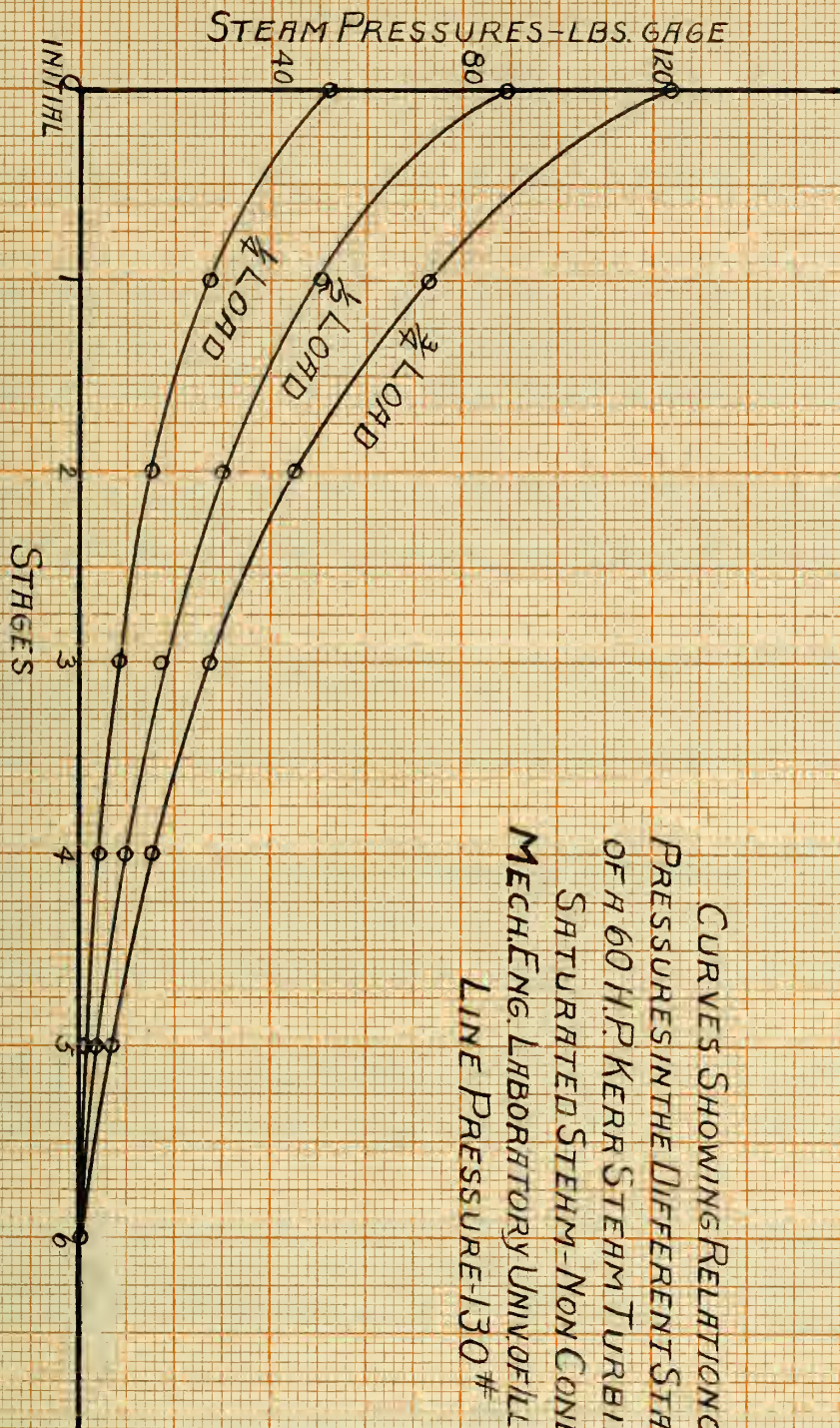
Geological Cross-section

The diagram illustrates a geological cross-section, showing the relationship between different rock units and structural features. The vertical axis represents elevation or depth, while the horizontal axis represents distance or position.

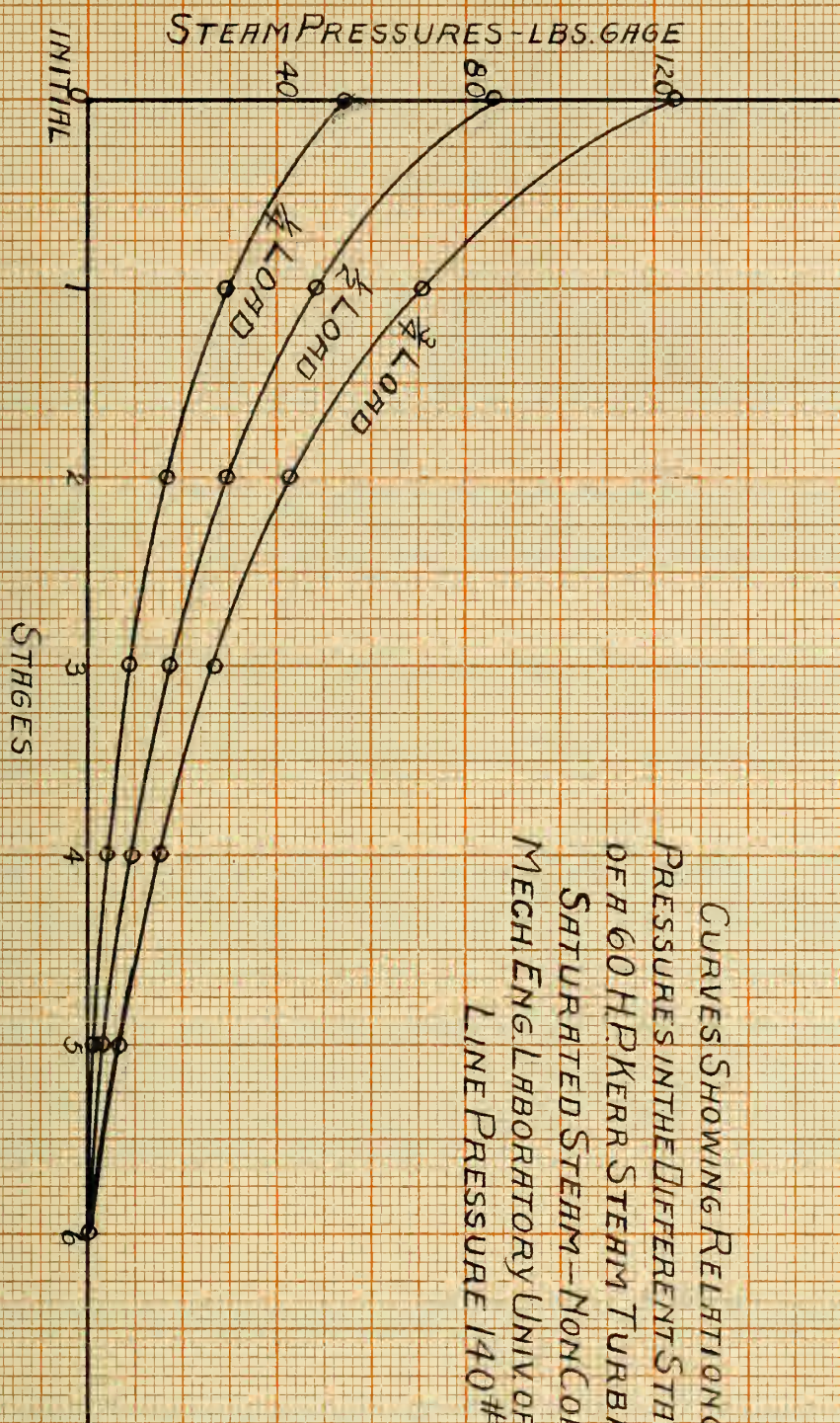
Key features include:

- Rock Units:** Various layers of rock are depicted, likely representing different geological periods or formations.
- Structural Features:** The diagram shows the presence of folds, faults, or other geological structures that have shaped the landscape.
- Topography:** The surface profile is indicated by a line, showing the elevation of the land.

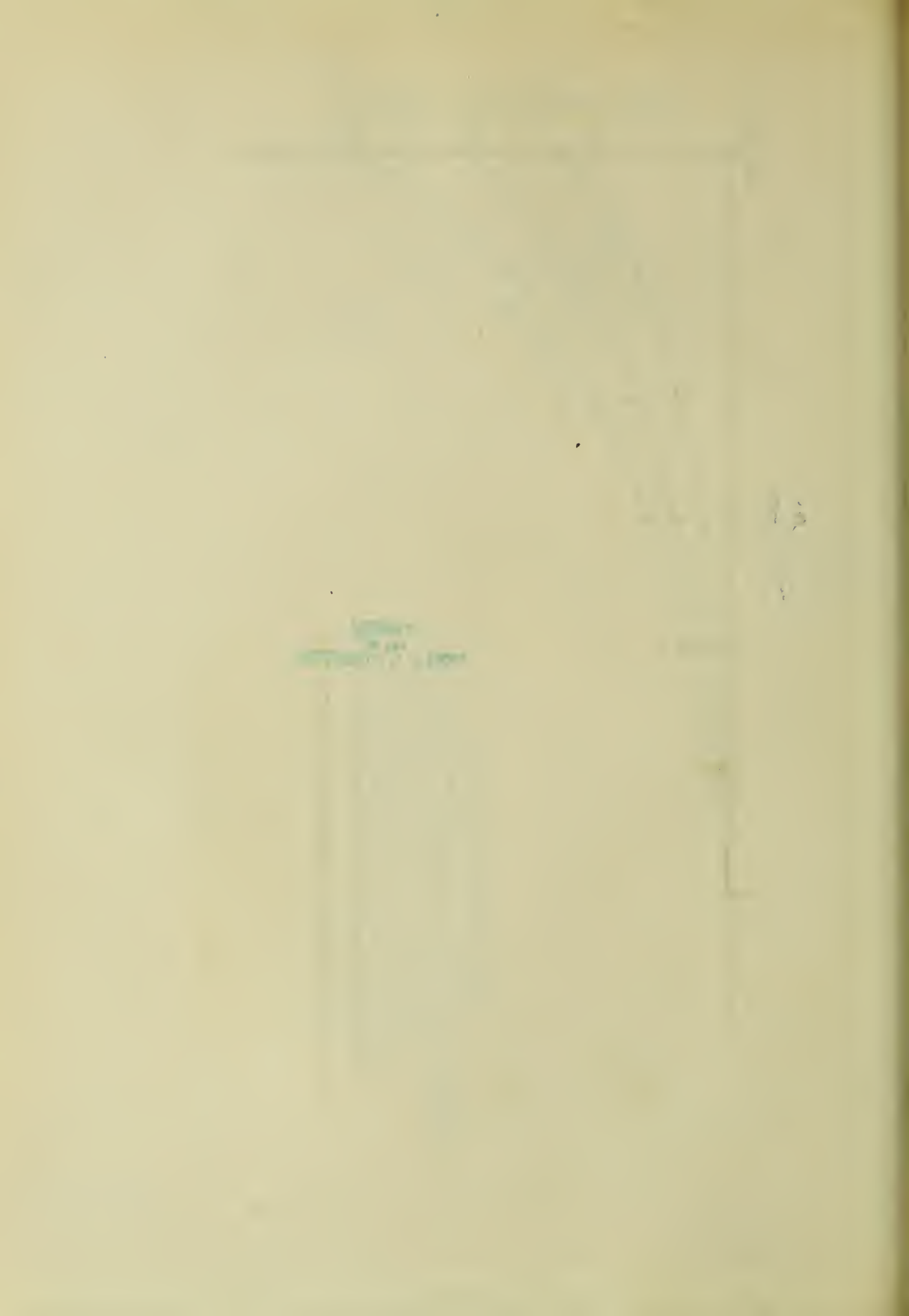
The cross-section provides a detailed view of the subsurface geology, allowing for the interpretation of the area's geological history and the processes that have shaped it.

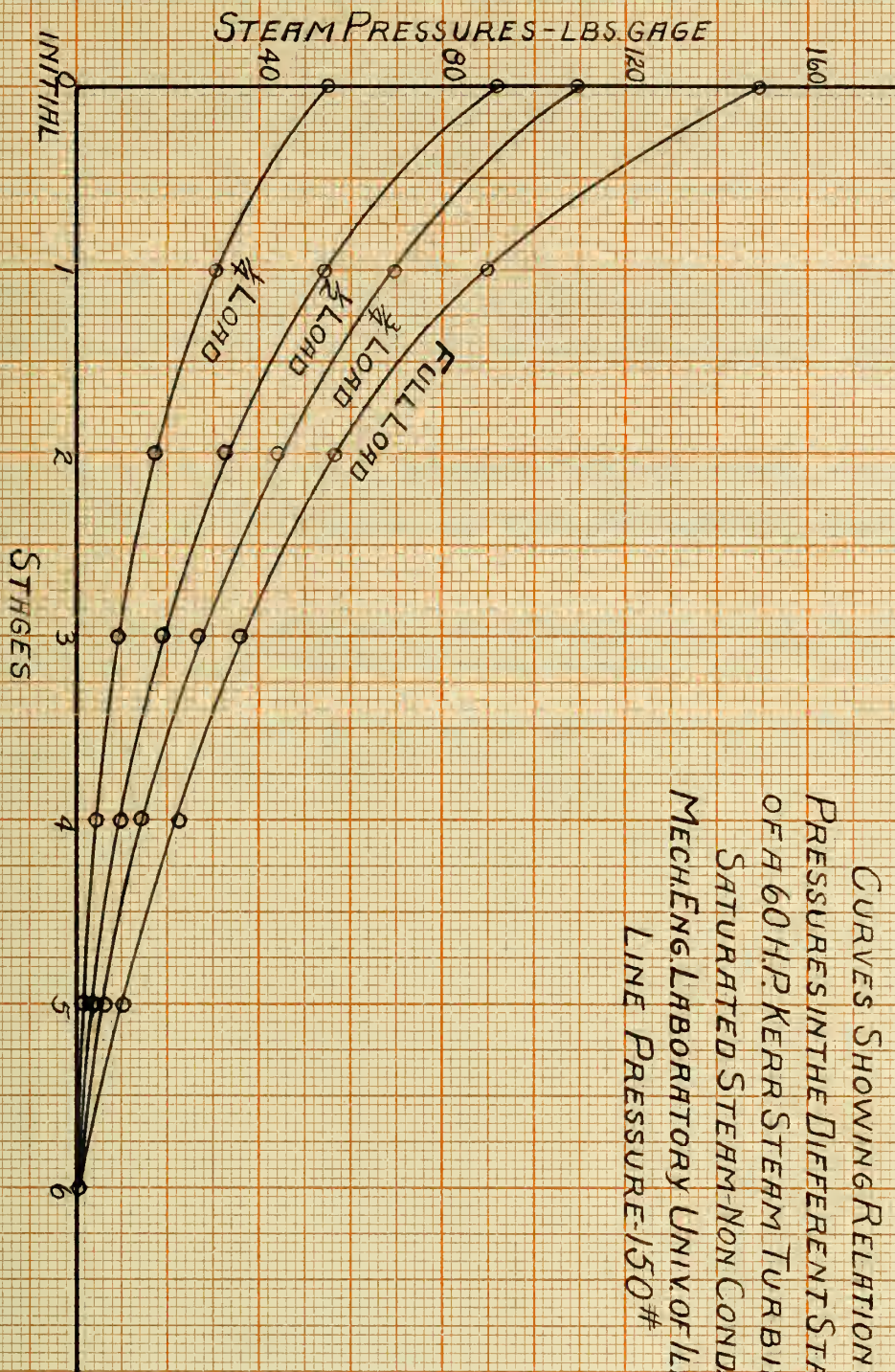


CURVES SHOWING RELATION OF
PRESSURES IN THE DIFFERENT STAGES
OF A 60 H.P. KERR STEAM TURBINE
SATURATED STEAM-NON COND.
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LINE PRESSURE-130 #

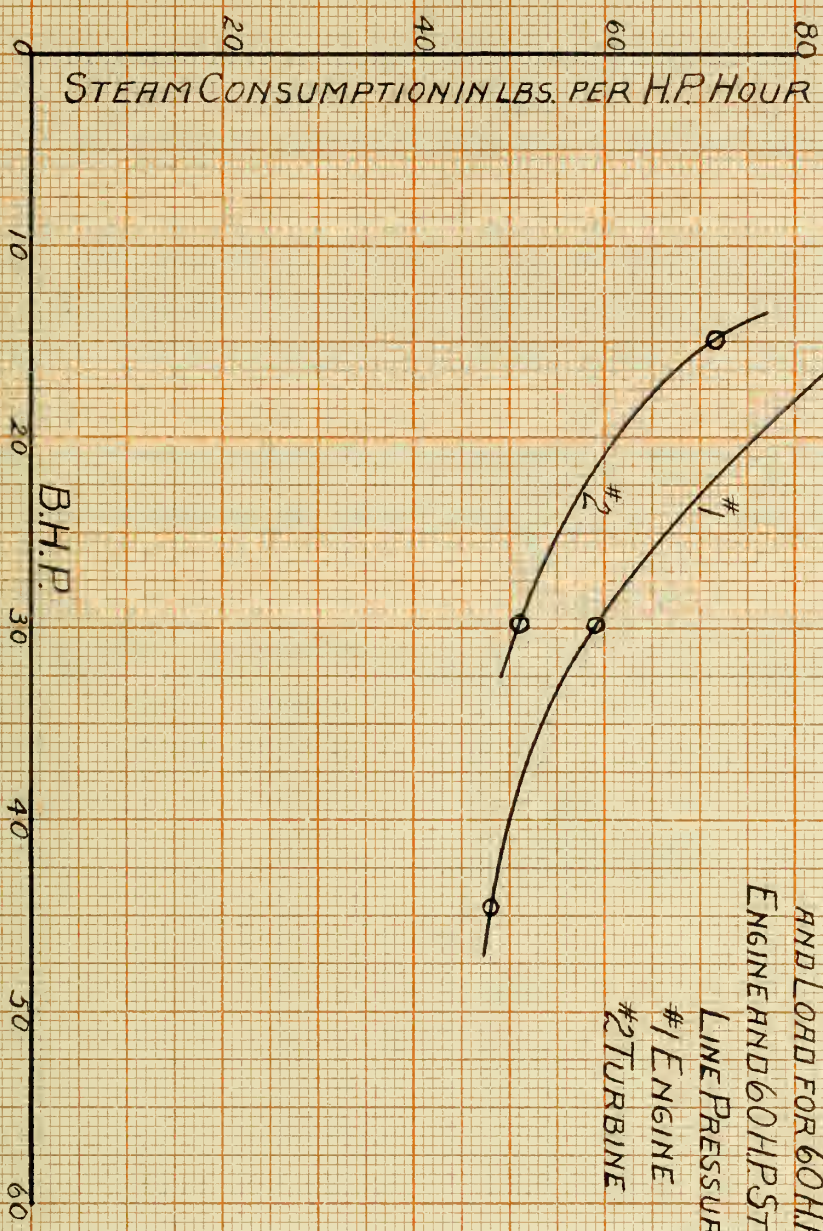


CURVES SHOWING RELATION OF
PRESSURES IN THE DIFFERENT STAGES
OF A 60 HP KERR STEAM TURBINE
SATURATED STEAM - NON COND
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LINE PRESSURE 140 #

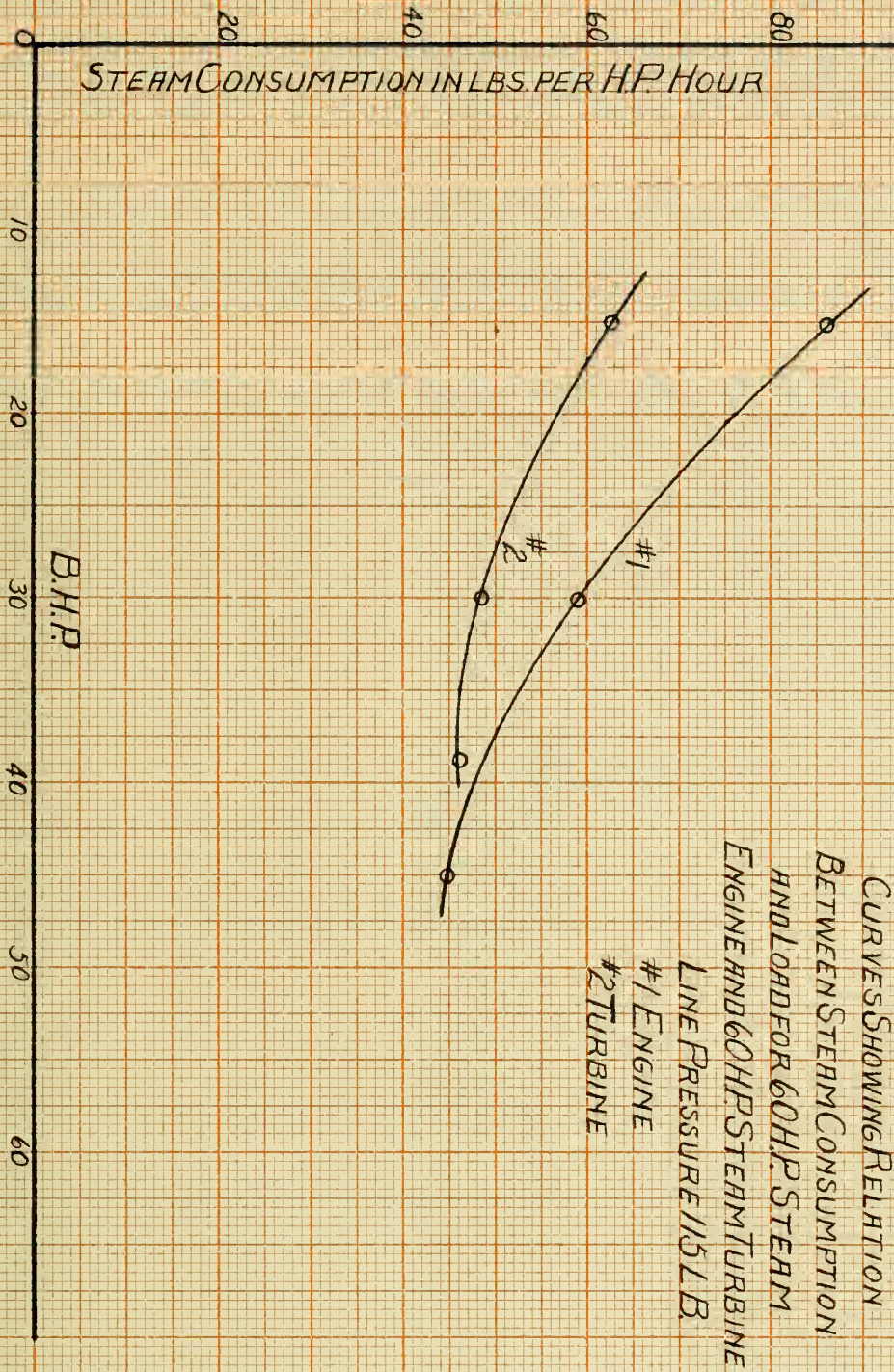


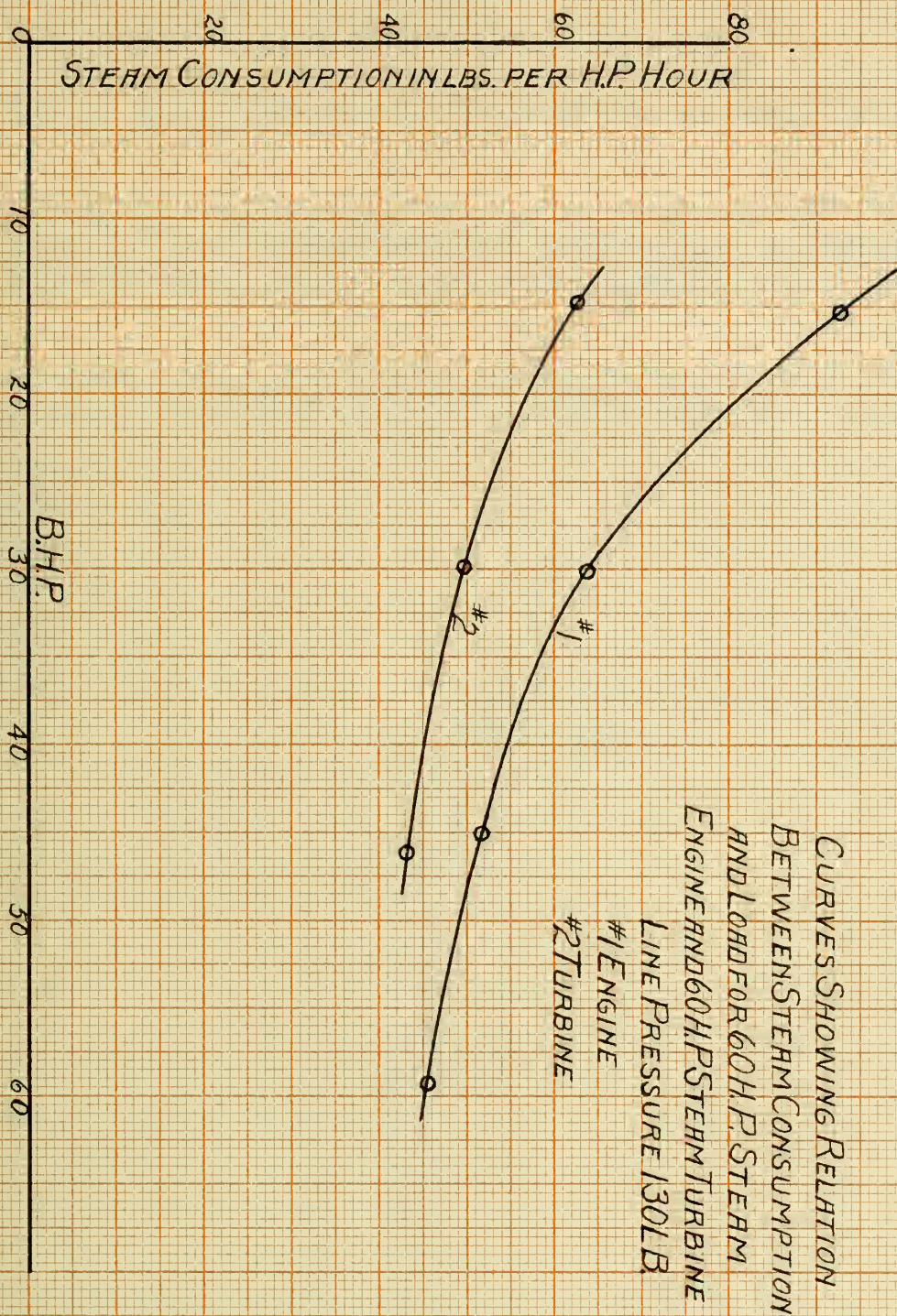


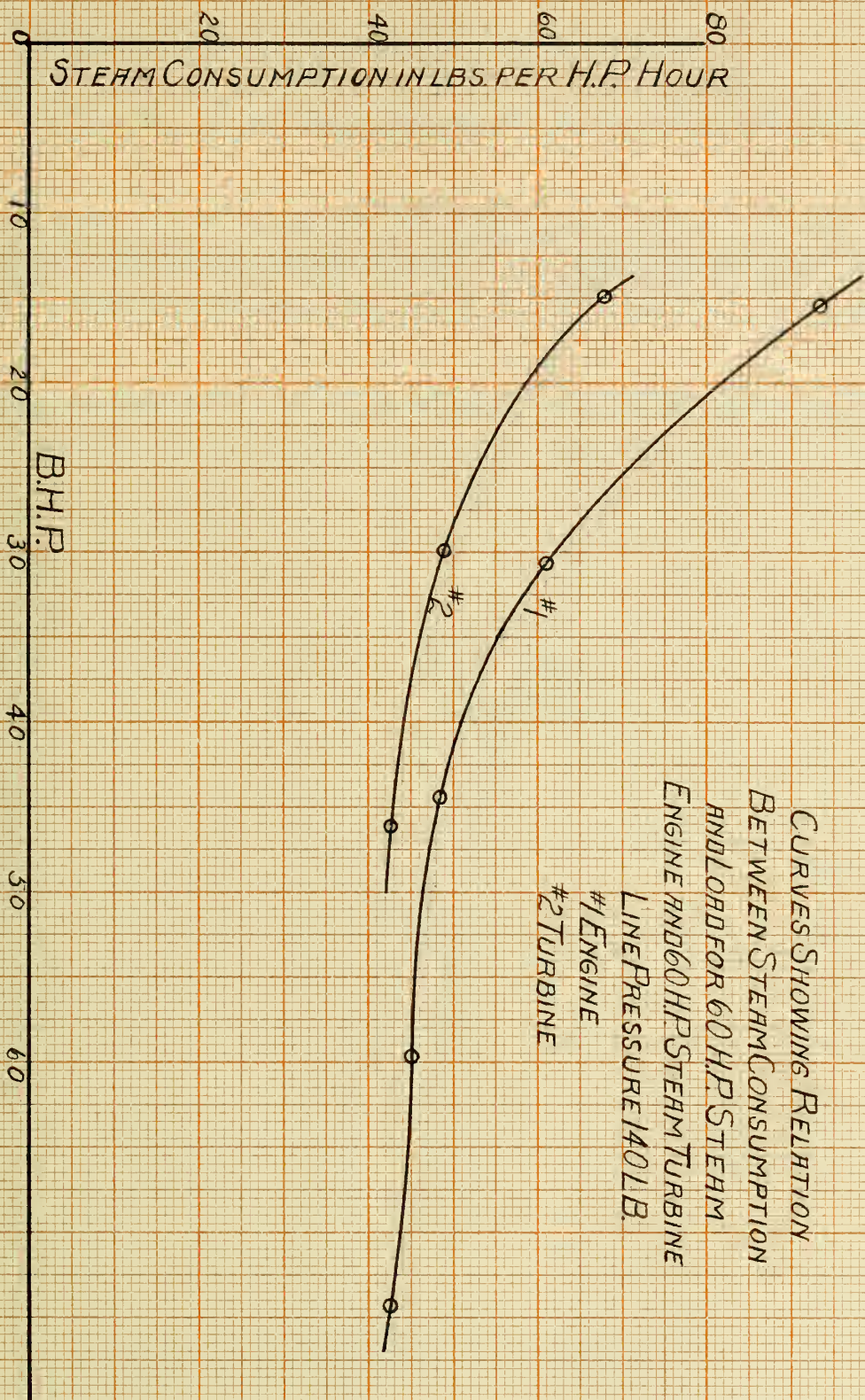
CURVES SHOWING RELATION OF
PRESSURES IN THE DIFFERENT STAGES
OF A 60 H.P. KERR STEAM TURBINE
SATURATED STEAM - NON COND.
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LINE PRESSURE - 150 #



CURVES SHOWING RELATION
BETWEEN STEAM ECONOMY
AND LOAD FOR 60 H.P. STEAM
ENGINE AND 60 H.P. STEAM TURBINE
LINE PRESSURE 100 LB.
#1 ENGINE
#2 TURBINE







STEAM CONSUMPTION IN LBS. PER H.P. HOUR

10

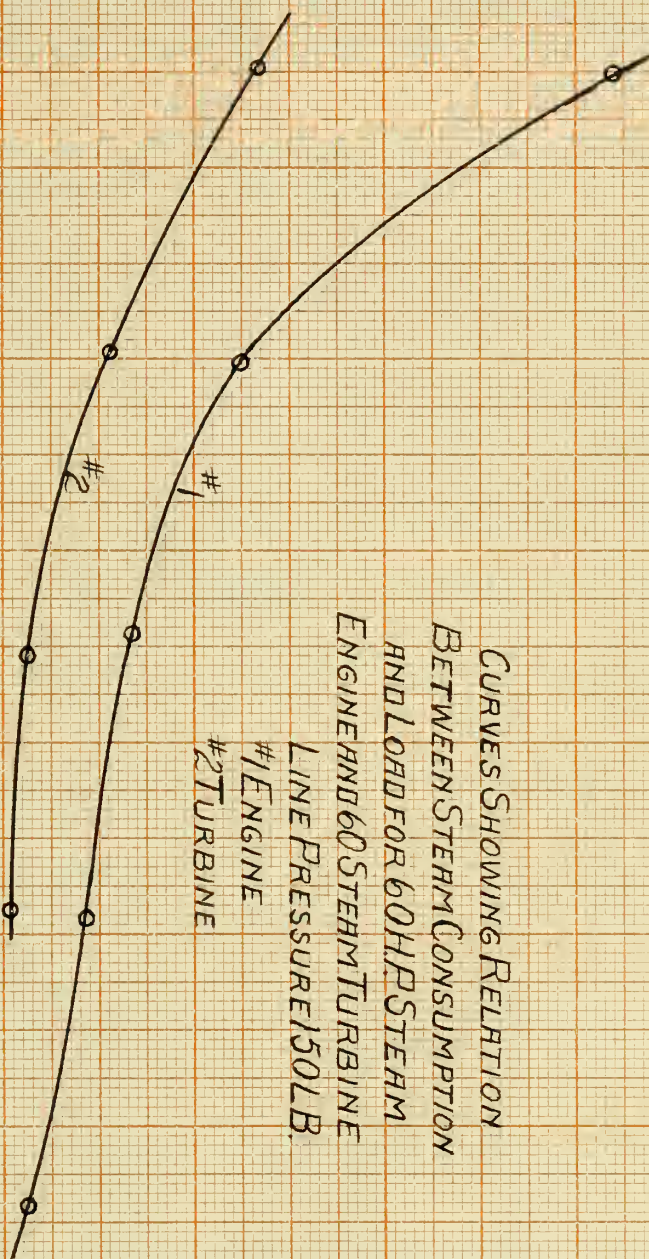
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B.H.P.

40

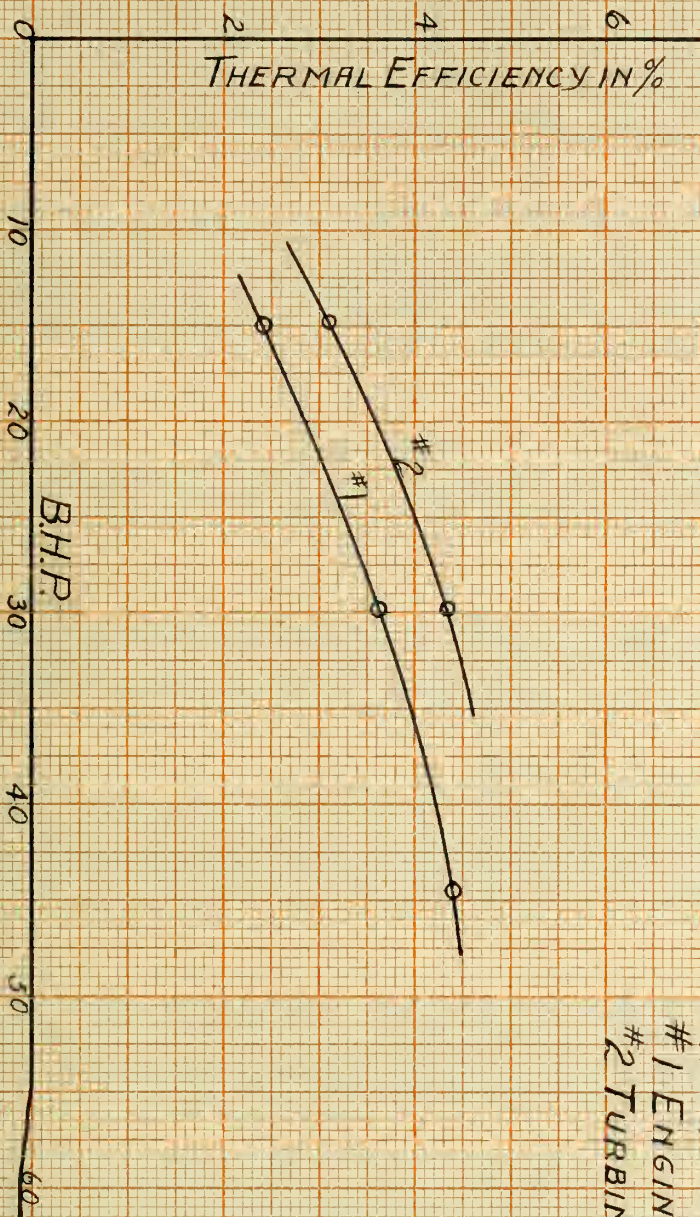
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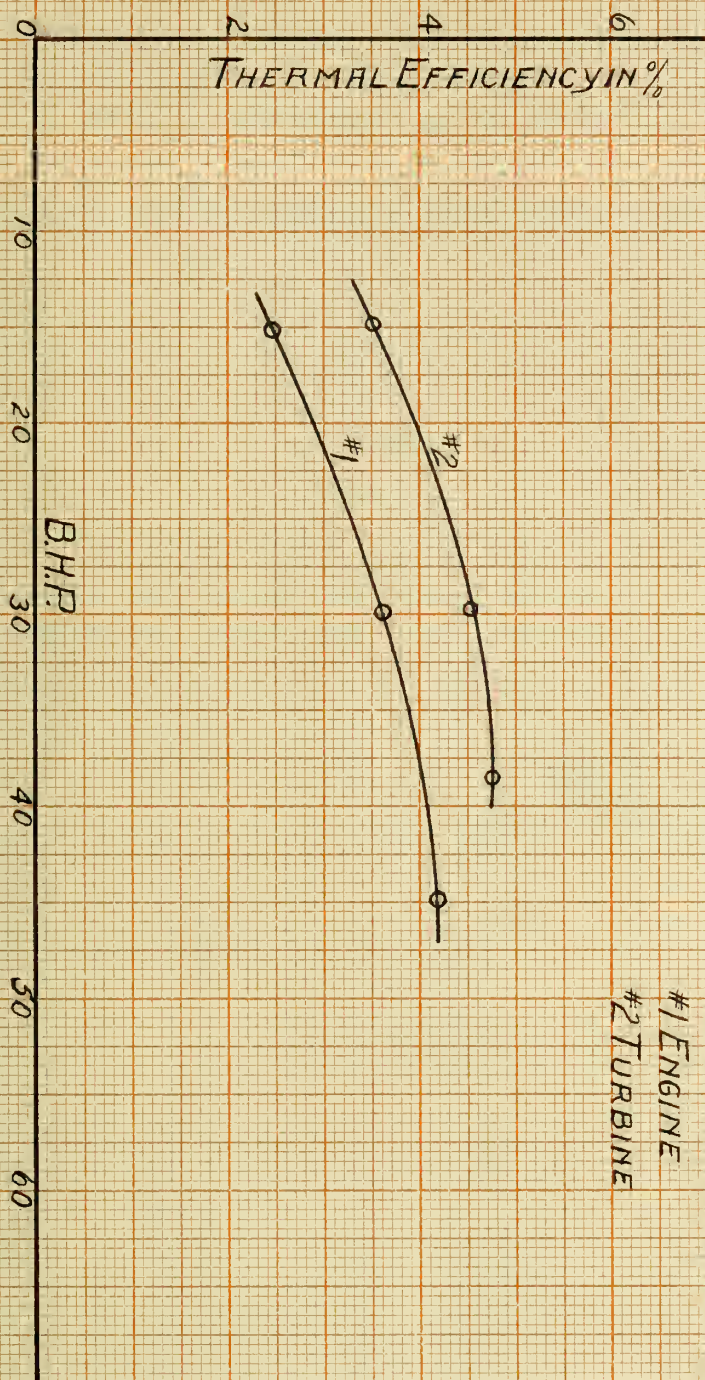


CURVES SHOWING RELATION
BETWEEN STEAM CONSUMPTION
AND LOAD FOR 60 H.P. STEAM
ENGINE AND 60 STEAM TURBINE
LINE PRESSURE 150 L.B.

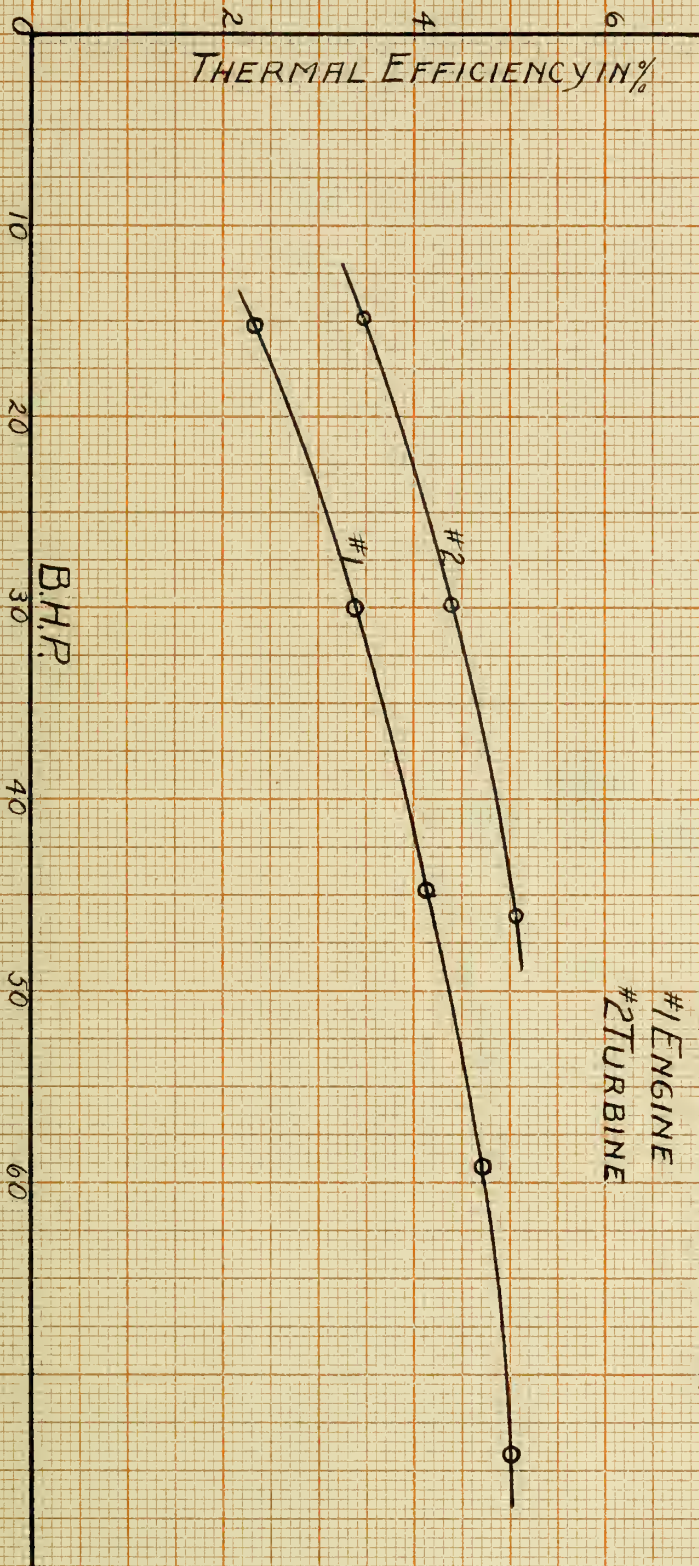
#1 ENGINE
#2 TURBINE



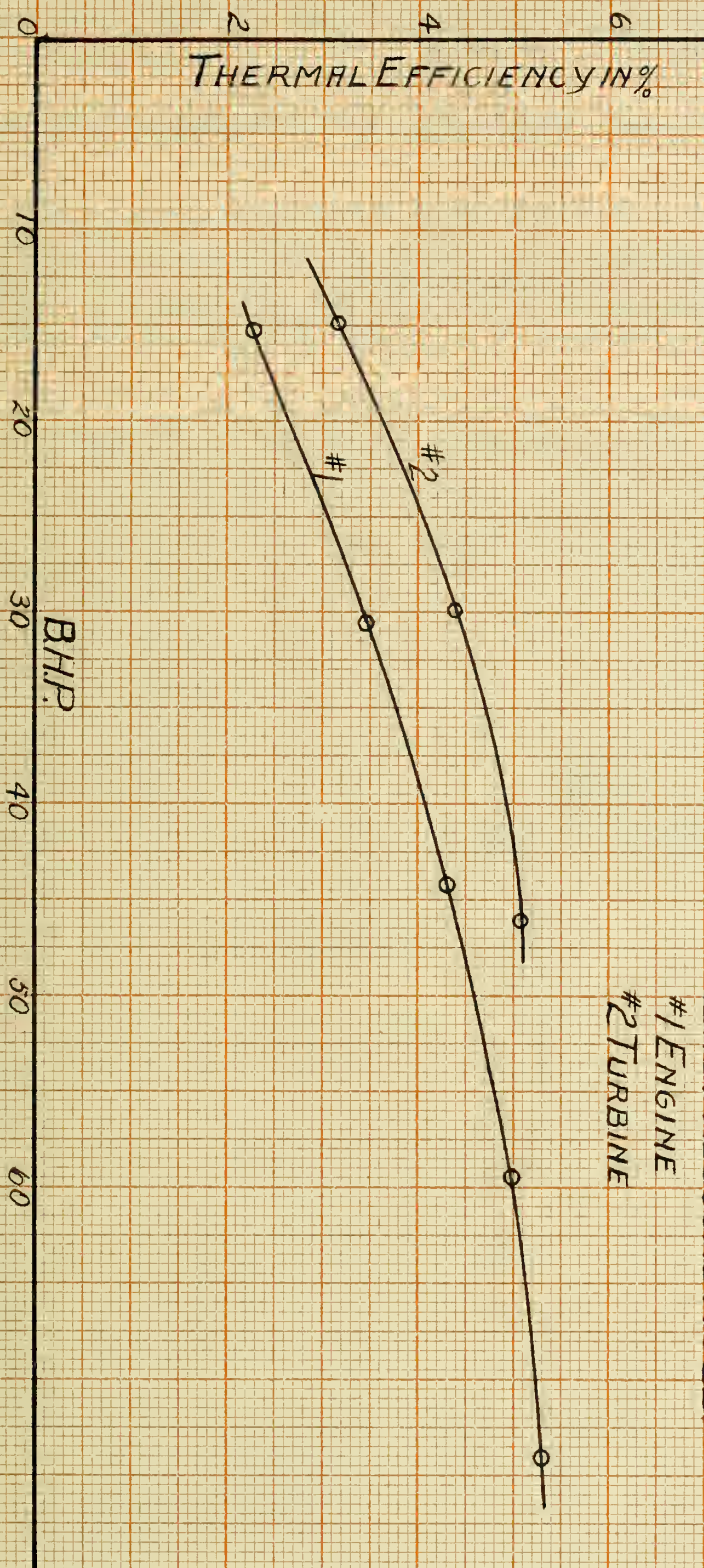
CURVES SHOWING RELATION
BETWEEN THERMAL EFFICIENCY
AND LOAD FOR 60 H.P. STEAM
ENGINE AND 60 H.P. STEAM TURBINE
LINE PRESSURE 100 LB.
#1 ENGINE
#2 TURBINE



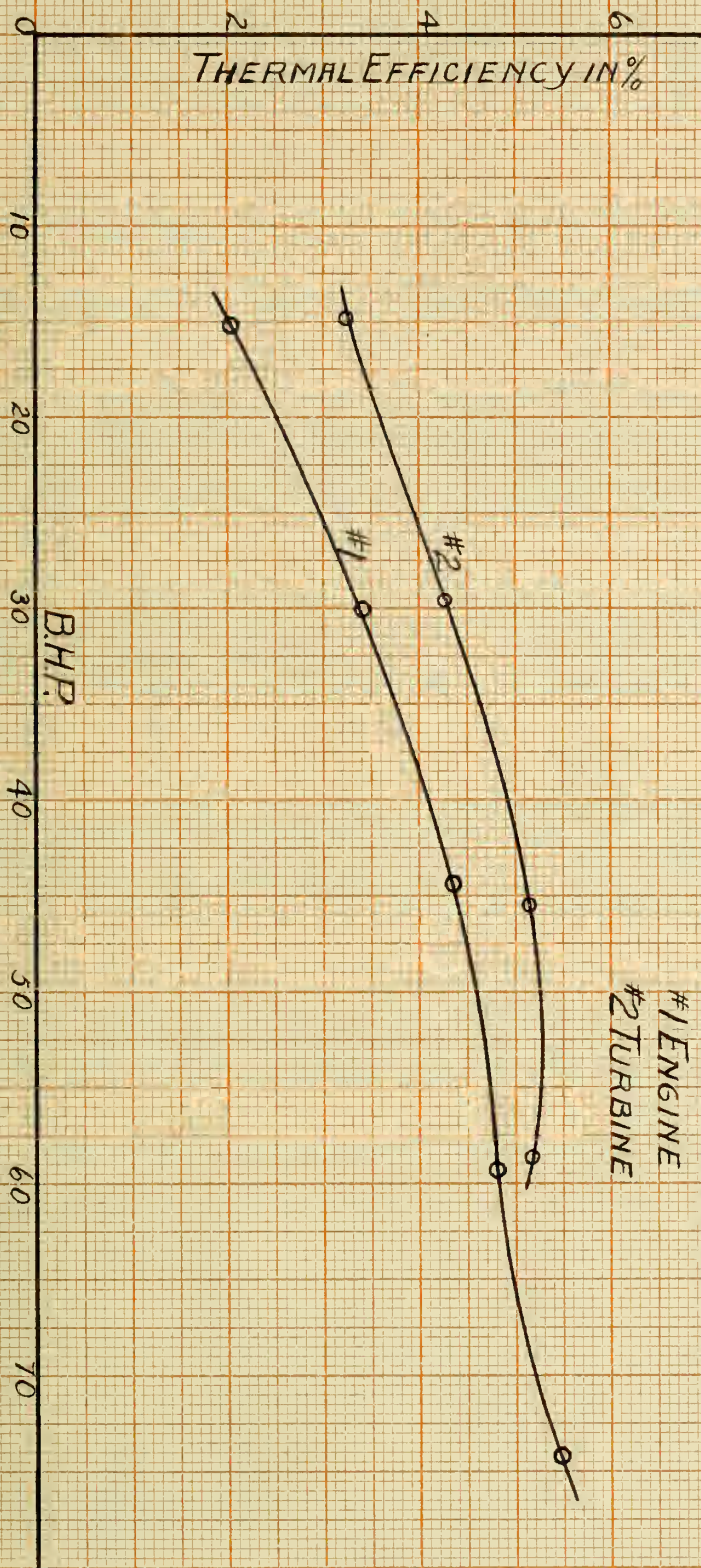
CURVES SHOWING RELATION
BETWEEN THERMAL EFFICIENCY
AND LOAD FOR 60 H.P. STEAM
ENGINE AND 60 H.P. STEAM TURBINE.
LINE PRESSURE 115 L.B.



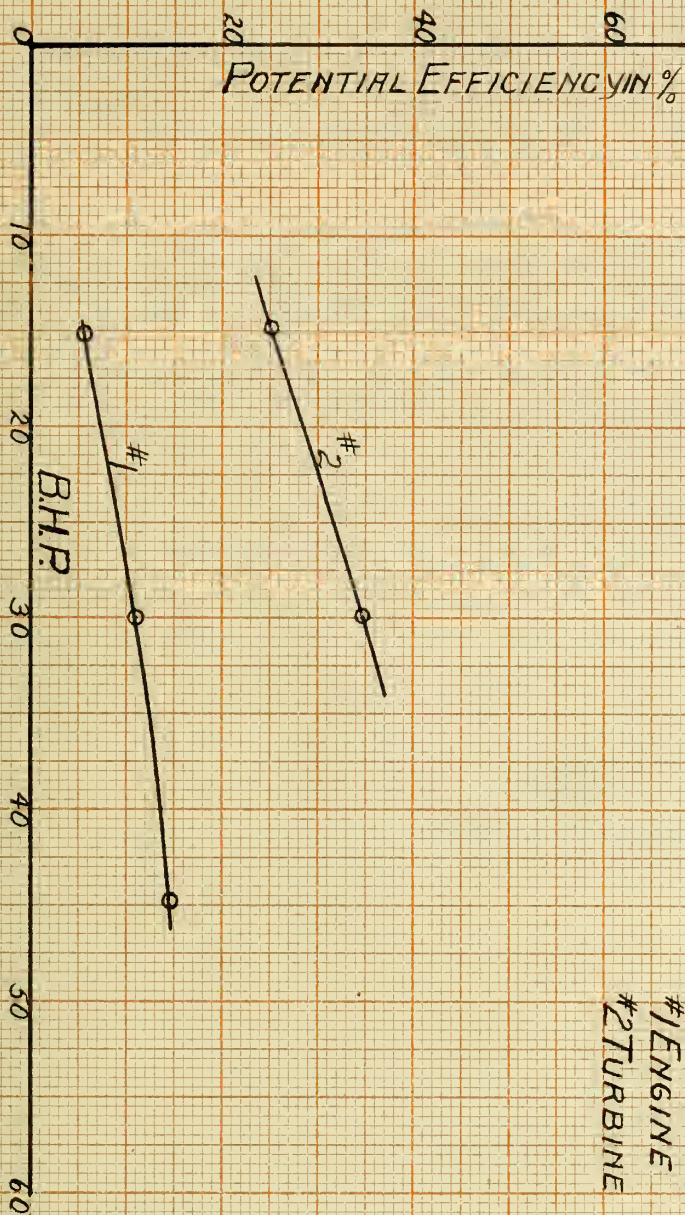
CURVES SHOWING RELATION
BETWEEN THERMAL EFFICIENCY
AND LOAD FOR 60 H.P. STEAM
ENGINE AND 60 H.P. STEAM TURBINE.
LINE PRESSURE 130 L.B.
#1 ENGINE
#2 TURBINE



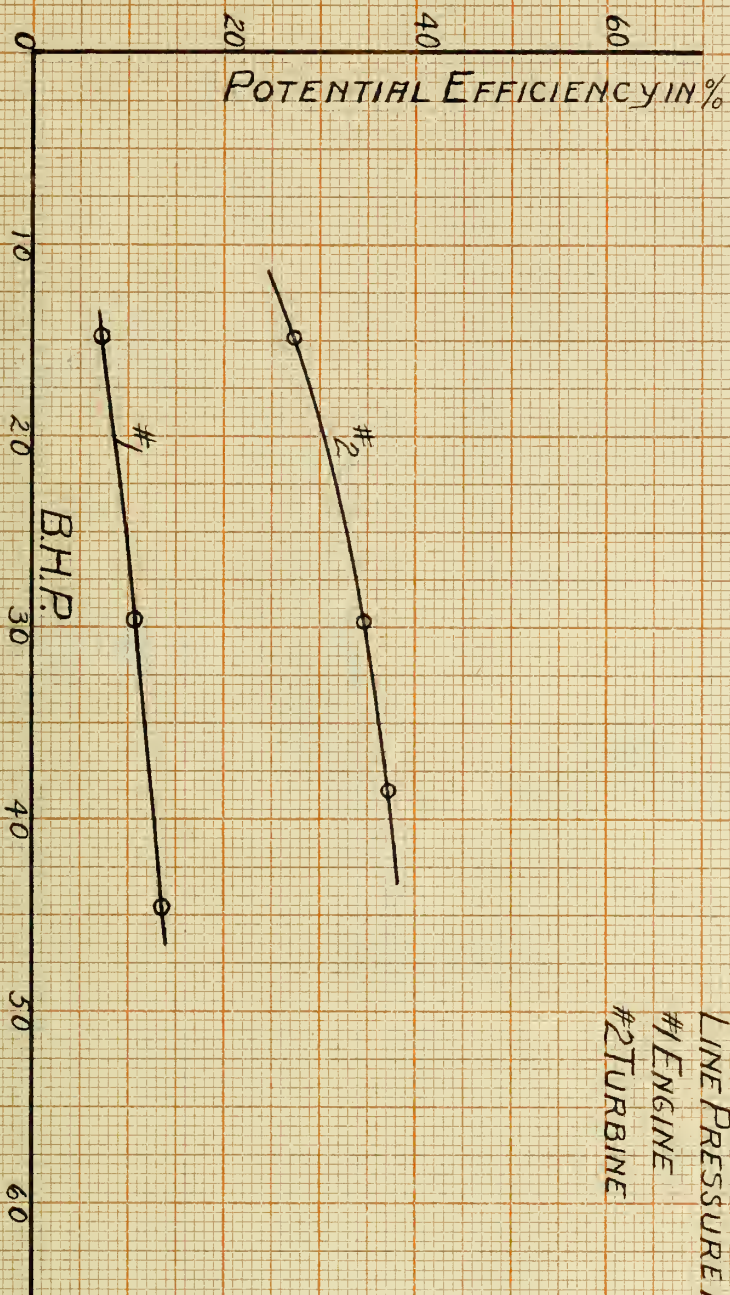
CURVES SHOWING RELATION
BETWEEN THERMAL EFFICIENCY
AND LOAD FOR 60 H.P. STEAM
ENGINE AND 60 H.P. STEAM TURBINE
LINE PRESSURE 140 L.B.
#1 ENGINE
#2 TURBINE



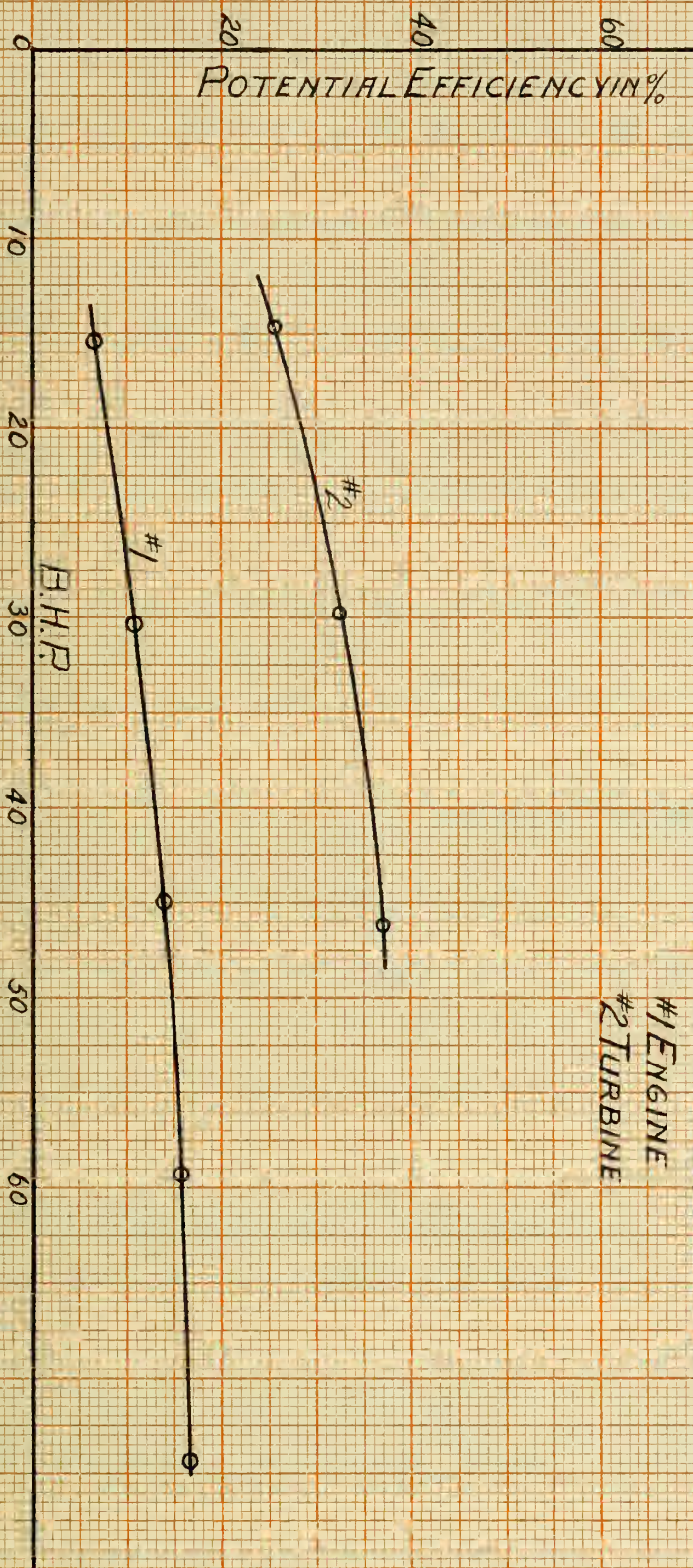
CURVES SHOWING RELATION
BETWEEN THERMAL EFFICIENCY
AND LOAD FOR 60 H.P. STEAM
ENGINE AND 60 H.P. STEAM TURBINE.
LINE PRESSURE 150 L.B.



CURVES SHOWING RELATION
 BETWEEN POTENTIAL EFFICIENCY
 AND LOAD FOR 60 H.P. STEAM
 ENGINE AND 60 H.P. STEAM TURBINE
 LINE PRESSURE 100 L.B.
 #1 ENGINE
 #2 TURBINE

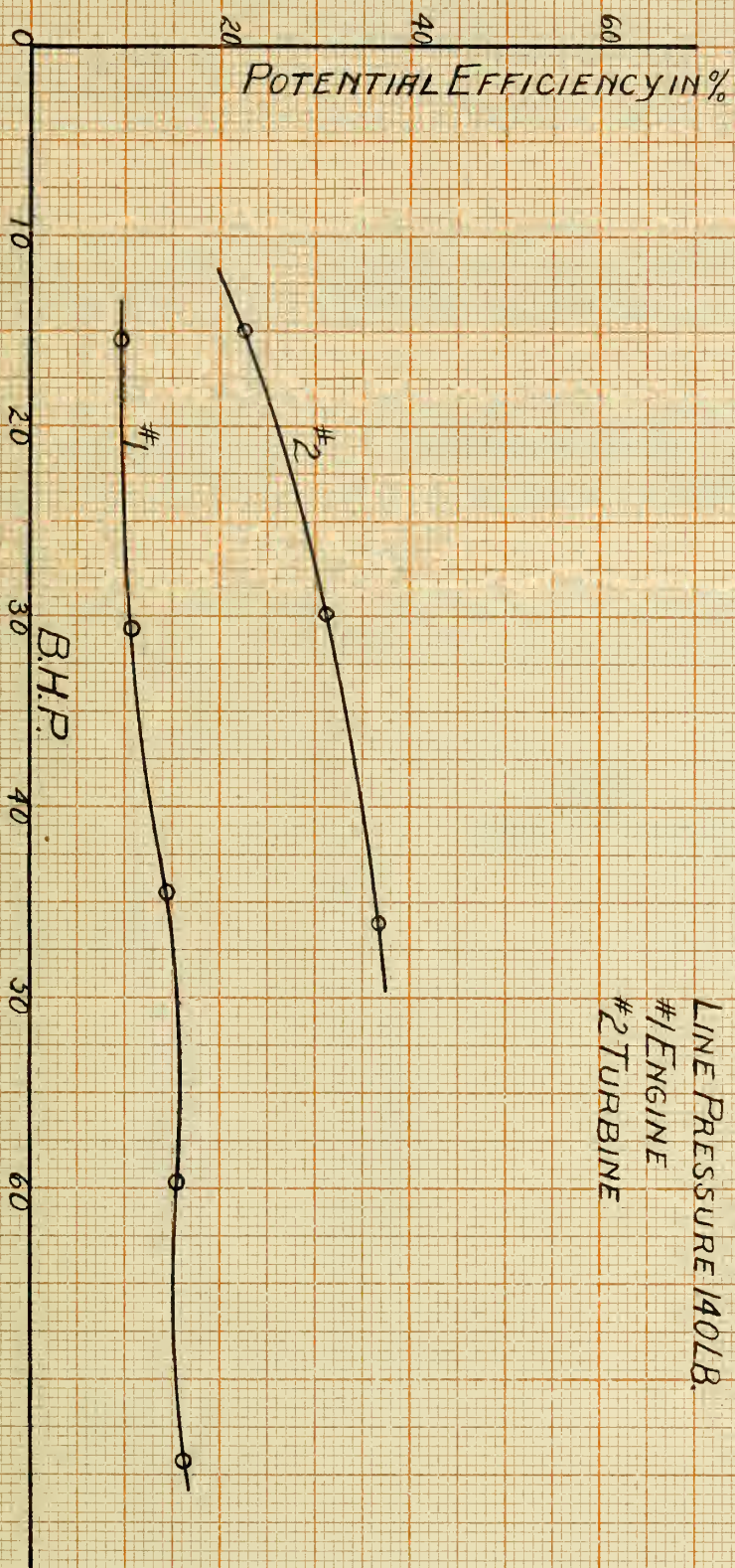


CURVES SHOWING RELATION
BETWEEN POTENTIAL EFFICIENCY
AND LOAD FOR 60 H.P. STEAM
ENGINE AND 60 H.P. STEAM TURBINE
LINE PRESSURE 115 L.B.
#1 ENGINE
#2 TURBINE

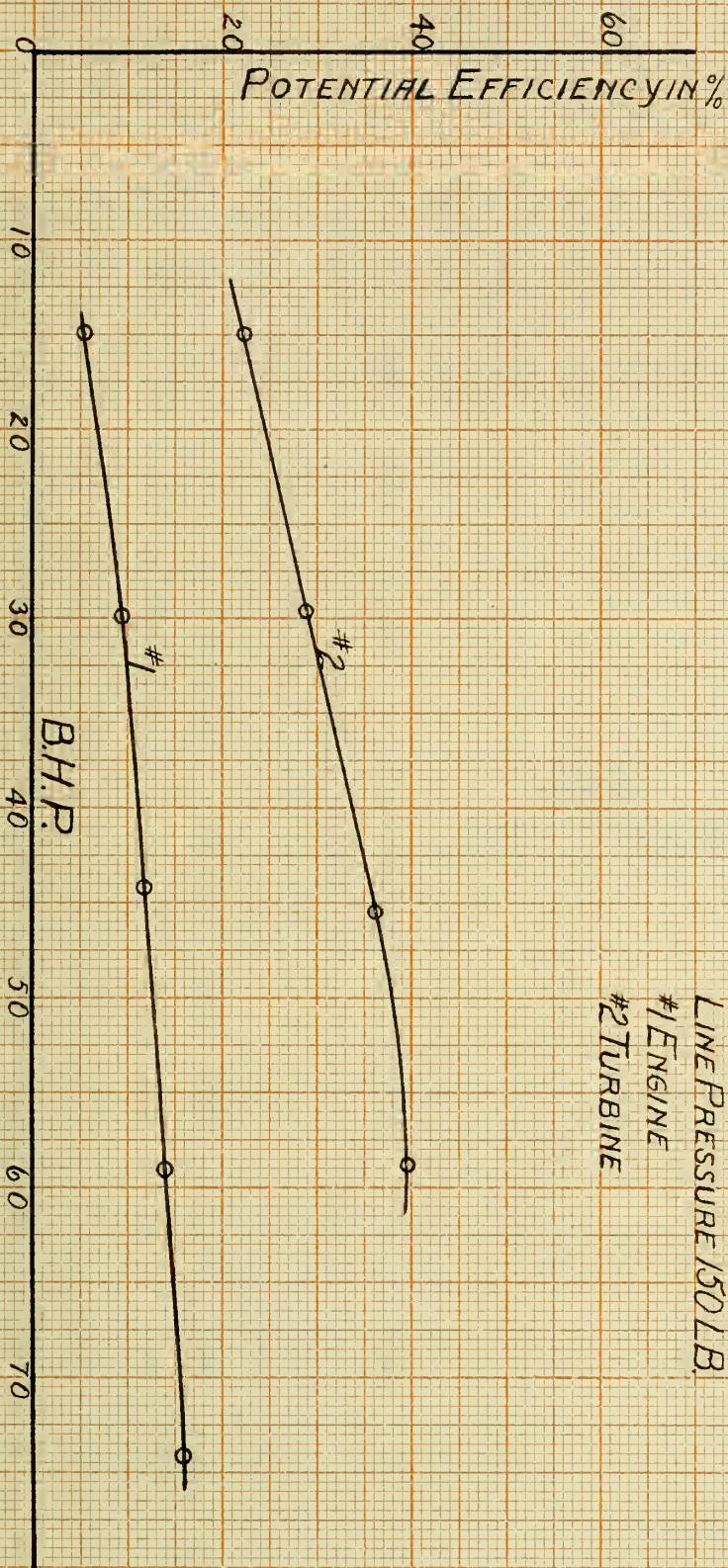


CURVES SHOWING RELATION
 BETWEEN POTENTIAL EFFICIENCY
 AND LOAD FOR 60 H.P. STEAM
 ENGINE AND 60 H.P. STEAM TURBINE
 LINE PRESSURE 130 L.B.

#1 ENGINE
 #2 TURBINE



CURVES SHOWING RELATION
 BETWEEN POTENTIAL EFFICIENCY
 AND LOAD FOR 60HP STEAM
 ENGINE AND 60HP STEAM TURBINE
 LINE PRESSURE 140 LB.
 #1 ENGINE
 #2 TURBINE



CURVES SHOWING RELATION
BETWEEN POTENTIAL EFFICIENCY
AND LOAD FOR 60 H.P. STEAM
ENGINE AND 60 H.P. STEAM TURBINE
LINE PRESSURE 150 L.B.

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 100 lb.

0 Load.

Date: - Jan. 2, '09.

J. F. Weiss ^{Eng} H. E. Christy.

No.	Time	R.P.M.	Cal. Press.	# Wt. Cond'd Steam	Temperatures			Stage	Pressures						
					Cal.	Ext	Inside		Outside	Enter	1	2	3	4	5
1	9:45	3580	100	0	270	217	65		30	20	9.5	38	2	1.3	.1
2	9:50	3588	100	39	271	218	65			20	9.7	38	2	1.3	.1
3	9:55	3591	100	41	271	217	65		30	20	9.8	38	2	1.3	.1
4	10:00	3610	100	42	267	218	65			20	9.8	38	2	1.3	.1
5	10:05	3602	100	40	255	218	67		31	20	9.8	38	2	1.3	.1
6	10:10	3596	100	40	254	218	56			20	9.8	38	2	1.3	.1
7	10:15	3619	100	42	261	218	62		30	20	9.8	38	2	1.3	.1
8	10:20	3599	100	40	262	219	66			20	9.8	38	2	1.3	.1
9	10:25	3589	100	39	262	220	66		31	20	9.8	38	2	1.3	.1
10	10:30	3603	100	45	265	220	66			20	9.8	38	2	1.3	.1
11	10:35	3608	100	43	267	221	67		31	20	9.8	38	2	1.3	.1
12	10:40	3628	100	35	267	222	67			20	9.8	38	2	1.3	.1
13	10:45	3650	100	41	263	220	63		32	20	9.8	38	2	1.3	.1
Averages		3605	100	40.6	264	219	65.4		31.6	20	9.8	3.8	2	1.3	.1

Steam Consumption

lb.

Hv. Thermal Eff.

Hv. B.H.P.

Hv. Quality of Steam 99.0%

Hv. Potential Eff.

Barometer 29.58"

Steam Economy and Efficiency Test of a 60 H.P. Kerr-Stearn Turbine.

Steam Pressure 100/lb.

$\frac{1}{4}$ Load.

Date: - Dec. 29, '08

J.F. Weiss ^{Eng} and H.E. Cristy.

No.	Time	R.P.M.	Col. Press.	# Wt. Cond. Steam	Temperatures		F.° Outside	Stage Pressures						
					Col.	Exit Inside		Enter	1	2	3	4	5	
1	12:25	3600	100	0	233	209	66	51	61	32.8	18.4	10.5	5.6	2.1
2	12:30	3586	100	93	233	209	66		61	32.9	18.5	10.6	5.6	2.1
3	12:35	3544	100	90	233	209	65	50	60	32.8	18.4	10.5	5.5	2.1
4	12:40	3597	100	97	234	209	65		60	32.2	18.2	10.3	5.3	2.0
5	12:45	3570	100	88	235	209	65	50	59	31.8	18.0	10.1	5.1	2.0
6	12:50	3600	100	93	236	209	65		59	31.9	18.0	10.1	5.1	2.0
7	12:55	3583	100	83	234	209	65	51	59	31.7	17.8	10.1	5.0	2.0
8	1:00	3598	100	97	232	209	65		59	31.9	18.0	10.1	5.1	2.0
9	1:05	3573	100	85	230	209	65	51	59	31.8	17.9	10.1	5.0	2.0
10	1:10	3573	100	90	229	209	65		59	31.9	18.0	10.1	5.0	2.0
11	1:15	3588	100	87	227	211	65	52	59	32.0	18.1	10.2	5.1	2.0
12	1:20	3609	100	95	228	211	66		60	32.3	18.2	10.2	5.1	2.0
13	1:25	3568	100	94	227	211	66	52	60	32.0	18.1	10.1	5.1	2.0
Averages		3585	100	91	231.4	209.7	65.3	51	59.6	32.2	18.1	10.2	5.2	2.0

Steam Consumption 71.21 lb.

Av. Thermal Eff. 3.09% Av. B.H.P. 14.89

Av. Quality of Steam 97.1%

Av. Potential Eff. 25% Barometer 29.35"

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 100 lb.

Date: Dec. 29, '08.

J.F. Weiss ^{eng} and H.E. Cristy.
1/2 Load.

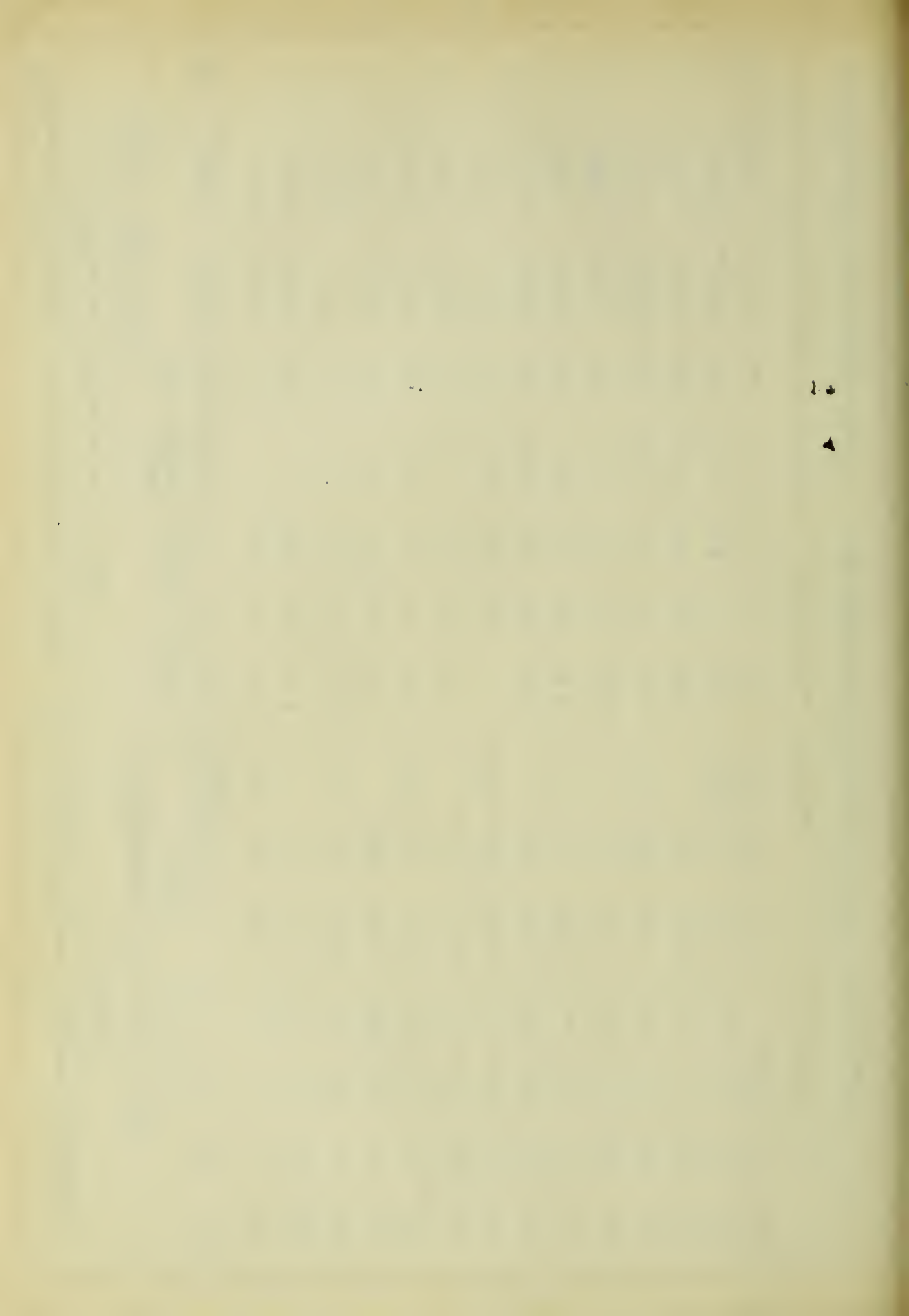
No.	Time	R.P.M	Col. Press.	# Wt. Cond. Steam	Temperatures F°			Stage Pressures						
					Col.	Ex't.	Inside	Outside	Enter	1	2	3	4	5
1	10:55	3647	100	0	234	210	64	48	94	52.6	31.6	19.2	10.7	4.1
2	11:00	3580	100	131	234	210	63		93	52.6	31.0	18.9	10.3	4.0
3	11:05	3570	100	138	234	210	63	49	94	52.8	31.2	19.0	10.3	4.0
4	11:10	3565	100	126	233	210	63		94	52.6	31.0	19.0	10.4	4.0
5	11:15	3592	100	142	233	210	63	49	93	52.8	31.1	19.0	10.6	4.0
6	11:20	3560	100	111	231	210	65		93	52.5	31.0	18.9	10.3	3.9
7	11:25	3580	100	126	230	210		50	94	52.7	31.0	18.9	10.3	4.0
8	11:30	3590	100	124	232	210	64		94	53.0	31.2	19.0	10.4	4.0
9	11:35	3609	100	138	232	210	64	51	96	52.8	31.0	18.9	10.2	4.0
10	11:40	3614	100	135	232	210	64		94	52.7	31.0	19.0	10.3	4.0
11	11:45	3585	100	127	231	210	65	51	94	52.7	31.0	19.0	10.4	4.0
12	11:50	3605	100	136	232	210	65		94	52.8	31.1	19.0	10.4	4.0
13	11:55	3550	100	130	234	210	66	52	93	52.7	31.0	19.0	10.3	4.0
Averages		3592	100	130.3	232	210	64	50	93.8	52.8	31.1	19.0	10.4	4.0

Steam Consumption 50.93 lb.

Fr. Thermal Efficiency 4.32% Fr. B.H.P. 29.82

Fr. Quality of Steam 97.1%

Fr. Potential Efficiency 34.9% Barometer 29.61"



Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 115 lb.

0 Load.

Date: - Jan. 2, 09

J.F. Weiss ^{Eng} H.E. Cristy

No.	Time	R.P.M.	Cal. Press	# Wt. Cond Steam	Temperatures F.°			Stage Pressures						
					Cal.	Ex't.	Indide	Outside	Enter	1	2	3	4	5
1	9:00	3700	115	0	264	212	52	28	25	11.8	5	2.8	1.7	.1
2	9:05	3701	115	49	265	212	52		25	11.9	5	2.8	1.7	.1
3	9:10	3735	115	44	266	213	53	29	25	11.9	5	2.8	1.7	.1
4	9:15	3732	115	46	266	214	49		25	12.0	5	2.8	1.7	.1
5	9:20	3729	115	45	263	213	47	30	25	11.9	5	2.8	1.7	.1
6	9:25	3751	115	45	271	215	52		25	11.9	5	2.8	1.7	.1
7	9:30	3725	115	43	272	216	62	30	25	11.9	5	2.8	1.7	.1
Averages.		3725	115	45.4	266.7	213.4	52.5	29.4	25	11.9	5	2.8	1.7	0.1

Steam Consumption

lb.

Hv Thermal Eff.

Hv B.H.P.

Hv Quality of Steam 98.6%

Hv Potential Eff.

Barometer 29.58"

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 115 lb. $\frac{1}{4}$ Load.

Date: Dec. 29, '08.

J.F. Weiss ^{Eng} H.E. Christy.

No.	Time	R.P.M.	Cal. Press.	# Wt. Cond. Steam	Temperatures		F°	Stage		Pressures					
					Cal.	Ext.		Inside	Outside	Enter	1	2	3	4	5
1	4:55	3599	115	0	218	211	63	40		57	30.5	12.1	10	4.9	2
2	5:00	3591	115	88	218	211	63	40		57	30.5	12.1	10	4.9	2
3	5:05	3603	115	90	221	211				58	31.0	12.3	10	4.9	2
4	5:10	3557	115	81	225	211	73			57	30.5	12.1	10	4.9	2
5	5:15	3548	115	84	221	211	66	42		57	30.5	12.1	10	4.9	2
6	5:20	3612	115	78	218	211	63			58	30.6	12.2	10	4.9	2
7	5:25	3591	115	83	219	211	63			58	30.6	12.2	10	4.9	2
8	5:30	3601	115	88	221	211	63	42		59	31.4	12.6	10.1	5.0	2
9	5:35	3603	115	76	220	211	63			59	31.4	12.2	10.1	4.9	2
10	5:40	3596	115	79	218	211	63	42		58	31.5	12.6	10.1	5.0	2
11	5:45	3563	115	76	218	211	62			58	31.5	12.7	10.1	5.0	2
12	5:50	3555	115	70	216	211	60	42		58	31.5	13.0	10.1	5.0	2
13	5:55	3591	115	81	217	211	60			58	31.2	12.7	10.1	5.0	2
Average		3582	115	81.2	219.1	211	63.5	41.3		57.8	30.9	12.4	10.0	4.9	2

Steam Consumption 62.95 lb.

Hv. Potential Eff. .272 Hv. B. H. P. 14.87

Hv. Quality of Steam 96.1%

Hv. Thermal Eff. .035

Barometer 29.35"



Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 115 lb.

Date:- Dec. 29, 08

J.F. Weiss ^{1/2} Load
and H.E. Christy

No.	Time	R.P.M.	Cal. Press.	# Wt. Cond. Steam	Temperatures F°		Stage Pressures							
					Cal.	Ex't	Inside	Outside	Enter	1	2	3	4	5
1	3:40	3590	115	0	237	212	60	42	90	49.5	29.0	12.5	9.7	3.8
2	3:45	3553	115	144	236	212			88	49.6	29.1	12.6	9.8	3.8
3	3:50	3555	115	104	235	212			91	50.5	30.4	13.2	10.0	3.9
4	3:55	3553	115	125	233	212	61	42	91	51.0	30.3	13.2	10.2	3.9
5	4:00	3542	115	124	229	212	61		91	51.5	30.6	13.5	10.3	4.0
6	4:05	3585	115	116	228	212	62		92	51.7	30.7	13.5	10.2	4.0
7	4:10	3540	115	123	231	212	62	42	92	51.5	30.5	13.4	10.1	4.0
8	4:15	3599	115	124	229	212	62		92	51.7	30.6	13.5	10.2	4.0
9	4:20	3579	115	115	229	212			91	51.7	30.6	13.5	10.2	4.0
10	4:25	3564	115	114	230	212	61	42	92	51.6	30.5	13.5	10.1	4.0
11	4:30	3550	115	147	231	212			92	51.8	30.7	13.5	10.2	4.0
12	4:35	3590	115	136	231	212			92	51.7	30.7	13.5	10.2	4.0
13	4:40	3560	115	125	228	212	68	42	92	51.7	30.6	13.5	10.2	4.0
Averages		3566	115	124.8	231.3	212	62.1	42	91.2	51.1	30.3	13.5	10.1	3.95

Steam Consumption 48.57 lb. Av. Thermal Eff. 4.51% Av. B.H.P. 29.65

Av. Quality of Steam 96.8% Av. Potential Eff. 34.9% Barometer 29.36 "

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine. Steam Pressure 115 lb. $\frac{3}{4}$ Load.

Date:- Dec. 29, 08

J.F. Weiss Eng H.E. Cristy.

No.	Time	R.P.M	Cal. Press.	# Wt. Cond'd Steam	Temperatures F°			Stroke Pressures.						
					Cal.	Ex't	Inside	Outside	Enter	1	2	3	4	5
1	2:25	3598	115	0	237	212	65	47	114	65.1	39.5	24.6	13.6	5.6
2	2:30	3663	115	151	238	212	64	45	113	65.0	39.4	24.5	13.6	5.7
3	2:35	3616	115	160	239	212	63		113	65.0	39.3	24.4	13.4	5.6
4	2:40	3566	115	155	236	212	62	44	112	64.3	39.1	24.3	13.3	5.6
5	2:45	3648	115	148	234	212	61		112	64.5	39.2	24.3	13.3	5.6
6	2:50	3700	115	153	236	212	61	43	112	64.7	39.2	24.3	13.4	5.6
7	2:55	3681	115	149	236	212	61		113	64.8	39.2	24.3	13.4	5.5
8	3:00	3590	115	148	236	212	61	43	112	64.5	39.1	24.3	13.4	5.6
9	3:05	3611	115	150	236	212	60		111	63.8	38.9	24.2	13.3	5.6
10	3:10	3600	115	156	238	212	61	42	112	63.7	38.7	23.7	13.2	5.5
11	3:15	3659	115	151	238	212			113	64.6	39.2	24.4	13.4	5.7
12	3:20	3672	115	163	237	212	62	42	112	64.6	39.1	24.3	13.4	5.7
13	3:25	3725	115	149	237	212	61		112	63.9	38.9	24.2	13.4	5.7
Averages		3649	115	152.3	236.8	212	61.8	43.7	112.3	64.6	39.1	24.3	13.4	5.6

Steam Consumption 46.04 lb. η Thermal Eff 4.75 % η B.H.P 38.50

η Quality of Steam 97.1 % η Potential Eff 36.4 % Barometer 29.35"

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 130 lb.

$\frac{1}{4}$ Load.

Date: - Dec. 31, '08

J.F. Weiss ^{eng} and H.E. Christy.

No.	Time	R.P.M.	Cal. Press.	# Wt. Cond. Steam	Temperatures F.°			Stage Pressures						
					Cal.	Ex't	Inside	Outside	Enter	1	2	3	4	5
1	1:10.5	3606	130	0	250	212	47	25	48	25.7	14.1	7.6	4.2	1.4
2	1:11.0	3595	130	81	250	212	47		51	26.7	15.0	8.2	4.3	1.5
3	1:11.5	3594	130	80	251	212	49	26	52	27.0	15.0	8.2	4.5	1.5
4	1:12.0	3570	130	82	253	212	49		52	27.1	15.2	8.3	4.6	1.6
5	1:12.5	3569	130	80	254	212	48	26	52	27.1	15.2	8.4	4.6	1.6
6	1:13.0	3652	130	85	253	212	48		53	27.2	15.4	8.5	4.6	1.6
7	1:13.5	3582	130	83	254	212		27	51	26.8	14.9	8.1	4.3	1.4
8	1:14.0	3594	130	82	252	212	47		51	26.7	14.8	8.1	4.2	1.4
9	1:14.5	3571	130	71	253	212	47	30	52	27.2	15.4	8.3	4.5	1.6
10	1:15.0	3591	130	81	255	212	57		52	27.1	15.3	8.3	4.5	1.6
11	1:15.5	3582	130	83	255	212	60	33	52	27.4	15.4	8.3	4.5	1.6
12	2:10.0	3598	130	71	253	212	50		53	27.5	15.4	8.4	4.5	1.6
13	2:10.5	3596	130	85	251	212	49	33	52	27.5	15.4	8.4	4.5	1.5
Averages		3592	130	80.3	252.6	212	49.8	28.5	51.5	27.0	15.1	8.2	4.4	1.5

Steam Consumption 62.95 lb.

Hv. Thermal Eff.

3.47%

Hv. B.H.P. 14.93

Hv. Quality of Steam 97.5%

Hv. Potential Eff. 25.5%

Barometer 29.72"

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 130 lb.

$\frac{1}{2}$ Load.

Date:- Dec. 31, 08

J.F. Weiss Eng H.E. Christy.

No.	Time	R.P.M.	Cal. Press.	# Wt. Cond. Steam	Temperatures F°			Stage Pressures.						
					Cal.	Ex't	Inside	Outside	Enter	1	2	3	4	5
1	11:45	3602	130	0	254	215	56	22	90	50.9	30.1	18.1	9.7	3.7
2	11:50	3603	130	136	252	214	53		90	50.9	30.1	18.1	9.7	3.8
3	11:55	3590	130	130	253	214	60	21	90	50.9	30.2	18.0	9.7	3.7
4	12:00	3605	130	125	253	214	63		90	51.0	30.0	18.1	9.8	3.7
5	12:05	3586	130	127	253	214	63	22	91	51.5	30.4	18.2	9.8	3.9
6	12:10	3700	130	130	254	214	63		90	51.0	30.2	18.2	9.8	3.8
7	12:15	3560	130	119	254	214	55	23	89	50.9	30.6	17.9	9.6	3.8
8	12:20	3610	130	125	251	214	63	23	89	50.6	29.8	17.9	9.6	3.8
9	12:25	3584	130	129	255	214	61		89	50.6	29.9	17.8	9.6	3.8
10	12:30	3628	130	131	254	214	65	23	89	50.4	29.9	17.8	9.6	3.8
11	12:35	3638	130	124	249	214	50		89	50.4	29.9	17.8	9.6	3.8
12	12:40	3550	130	127	251	214	47	24	89	50.4	29.8	17.6	9.4	3.8
13	12:45	3582	130	121	247	214	47	24	88	50.2	29.6	17.4	9.3	3.7
Averages		3594	130	127	253	214	57.4	23.6	89.5	50.7	29.97	16.8	9.6	3.77

Steam Consumption 49.68 lb. H.P. Thermal Eff. 4.39% H.P. B.H.P. 29.91

H.P. Quality of Steam 97.5% H.P. Potential Eff. 32.2% Barometer 29.75"

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 130 lb.

Date:- Dec. - 31, 08

J.F. Weiss ^{Org} H.E. Cristy.
^{3/4} Load.

No.	Time	R.P.M.	Col. Press	# Wt. Cond. Steam	Temperatures		F°		Stage		Pressures.				
					Col.	Exit	Inside	Outside	Enter	1	2	3	4	5	
1	10:30	3572	130	0	255	214	48	18	123	71.5	43.7	27.0	14.6	6.3	
2	10:35	3652	130	161	257	214	48	18	124	72.3	44.6	27.2	14.7	6.6	
3	10:40	3570	130	163	257	214	48		123	71.8	44.0	27.0	14.7	6.6	
4	10:45	3575	130	157	255	214	47	18	123	71.8	44.0	27.0	14.7	6.6	
5	10:50	3568	130	170	256	214	60		123	71.8	44.0	27.0	14.7	6.6	
6	10:55	3688	130	173	257	214	49	20	124	72.4	44.3	27.3	14.8	6.7	
7	11:00	3692	130	176	255	214	50	20	124	72.5	44.4	27.4	14.8	6.7	
8	11:05	3650	130	168	257	214	59		124	73.1	44.8	27.5	14.9	6.8	
9	11:10	3602	130	176	257	214	61	20	124	72.6	44.5	27.4	14.9	6.7	
10	11:15	3675	130	174	259	214	62		124	72.5	44.5	27.4	14.9	6.7	
11	11:20	3640	130	167	259	214	63	20	124	72.4	44.5	27.3	14.9	6.7	
12	11:25	3707	130	170	258	214	52		124	72.2	44.4	27.3	14.9	6.7	
13	11:30	3658	130	176	254	214	52	20	124	72.1	44.3	27.2	14.9	6.7	
Averages		3635	130	169.2	256.3	214	53.7	19.2	123.7	72.2	44.3	27.2	14.8	6.65	

Steam Consumption 43.06 lb.

Av. Thermal Eff. 50.4%

Av. B.H.P. 46.11

Av. Quality of Steam 97.8%

Av. Potential Eff. 37.0%

Barometer 29.75"

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 140 lb.

$\frac{1}{4}$ Load

Date: Jan. 2, 09. J. F. Weiss Eng. H. E. Christy.

No.	Time	R.P.M.	Cal. Press.	# Wt. Cons'd Steam	Temperatures F.			Stage Pressures						
					Cal.	Ex't	Inside	Outside	Enter	1	2	3	4	5
1	3:10	3562	140	0	283	213	71	37	54	28.1	15.8	9.1	4.5	1.8
2	3:15	3570	140	85	282	212	71		54	28.5	16.0	9.2	4.5	1.8
3	3:20	3579	140	82	281	212	71	37	54	28.3	15.9	9.2	4.5	1.8
4	3:25	3581	140	79	282	212	72		54	28.3	15.8	9.2	4.5	1.8
5	3:30	3590	140	86	278	212	73	37	54	28.5	15.9	9.2	4.5	1.8
6	3:35	3593	140	87	281	212	74		54	28.5	16.0	9.2	4.5	1.8
7	3:40	3615	140	84	281	212	71	37	54	28.5	16.0	9.2	4.5	1.8
8	3:45	3592	140	85	280	212	60		54	28.5	16.0	9.2	4.5	1.8
9	3:50	3597	140	86	280	212	60	37	54	28.5	16.0	9.2	4.5	1.8
10	3:55	3620	140	88	282	212	61		54	28.5	16.0	9.2	4.5	1.8
11	4:00	3635	140	81	283	212	68	37	54	28.5	16.0	9.2	4.5	1.8
12	4:05	3600	140	82	280	212	70		54	28.5	16.0	9.2	4.5	1.8
13	4:10	3626	140	88	276	212	71	37	54	28.5	16.0	9.2	4.5	1.8
Averages		3597	140	84.7	280.7	212	68.4	37	54	28.4	16.0	9.2	4.5	1.8

Steam Consumption 67.81 lb. Fr. Thermal Eff. 31.7% Fr. B.H.P. 14.95
 Fr. Quality of Steam 98.9% Fr. Potential Eff. 22.5% Barometer 29.58"

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 140 lb.

$\frac{1}{2}$ Load.

Date: Jan. 2, '09.

J.F. Weiss ^{Eng} H.E. Christy.

No.	Time	R.P.M.	Cal. Press.	# Wt. Cond. Steam	Temperatures F°			Stage		Pressures.				
					Cal.	Ext	Inside	Outside	Enter	1	2	3	4	5
1	2:00	3550	140	0	282	213	60	37	86	48.2	28.5	16.8	8.9	3.1
2	2:05	3560	140	125	282	213	60		85	48.1	28.5	16.8	8.9	3.0
3	2:10	3600	140	121	282	213	63	37	86	48.3	28.6	16.9	8.9	3.1
4	2:15	3569	140	122	284	213	68		85	48.2	28.5	16.9	8.9	3.1
5	2:20	3690	138	124	284	213	69	37	88	49.5	29.3	17.5	9.3	3.8
6	2:25	3688	137	122	284	213	69		87	49.5	29.3	17.5	9.3	3.8
7	2:30	3523	136	121	276	213	69	37	85	48.5	28.6	16.9	8.9	3.7
8	2:35	3609	137	122	266	213	69		88	49.5	29.3	17.6	9.3	3.2
9	2:40	3608	140	120	272	213	69	37	85	49.5	29.2	17.6	9.2	3.7
10	2:45	3614	140	125	279	213	69		86	48.3	28.5	16.7	8.9	3.5
11	2:50	3592	140	125	280	213	68	37	85	48.1	28.3	16.7	8.9	3.5
12	2:55	3593	140	123	280	213	69		86	48.0	28.1	16.6	8.9	3.5
13	3:00	3585	140	139	282	213	70	37	85	48.7	28.7	17.1	8.9	3.6
Averages		3599	139	124	278.4	213	67	37	86	48.6	28.7		9.0	3.4

Steam Consumption 48.99 lb.

Hv. Thermal Eff.

4.39%

Hv. B.H.P.

29.98

Hv. Quality of Steam 98.8%

Hv. Potential Eff. 31.1%

Barometer 29.58"



Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine.

Steam Pressure 140 lb.

Date: Jan. 2, 09. J.F. Weiss ^{2nd} H.E. Christy.

No.	Time	R.P.M.	Cal. Press.	# Wt. Cond. Steam	Temperatures F°			Stage	Pressures					
					Cal.	Ext	Inside		1	2	3	4	5	
1	11:50	3570	140	0	273	216	69	33	126	72.8	39.8	27.8	15.5	7.0
2	11:55	3569	140	174	268	216	70	33	124	71.5	38.9	27.5	15.1	6.8
3	12:00	3617	140	169	265	216	70		129	74.3	41.3	28.4	15.8	7.1
4	12:05	3589	140	174	270	214	65	34	123	70.0	43.0	26.9	14.8	6.7
5	12:10	3586	140	165	271	214	60		121	70.0	43.0	26.7	14.7	6.6
6	12:15	3597	140	161	269	214	58	34	120	68.9	42.1	26.3	14.5	6.4
7	12:20	3578	140	186	262	214	57		122	70.5	43.0	26.6	14.7	6.6
8	12:25	3578	140	167	261	214	57	34	121	69.8	42.7	26.4	14.6	6.5
9	12:30	3570	140	166	268	214	62		121	69.6	42.5	26.3	14.5	6.5
10	12:35	3594	140	163	272	214	67	35	122	70.9	42.9	26.6	14.6	6.6
11	12:40	3560	140	165	272	214	69		122	69.8	42.8	26.5	14.5	6.4
12	12:45	3561	140	166	274	214	70		121	69.6	42.3	26.3	14.4	6.3
13	12:50	3561	140	163	272	214	70	35	124	70.2	43.0	26.7	14.7	6.4
Averages		3577	140	166.6	269	214.5	65	34	122.8	70.6	42.1	26.8	14.8	6.6

Steam Consumption 42.93 lb. H.P. Thermal Eff. 50.5% H.P. B.H.P. 46.02

H.P. Quality of Steam 98.2% H.P. Potential Eff. 36.7% Barometer 29.58"

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine. Steam Pressure 150 lb.

Date: - Mch. 27, 09

J. F. Weiss ¹/₄ Load.
H. E. Christy.

No.	Time	R. P. M.	Cal Press	Wt. Cond Steam	Temperatures			Stage Pressures						
					Cal.	Ex't	Inside	Outside	Enter.	1	2	3	4	5
1	2:33	3558	149	0	266	211.5	67	51	56	31.5	17.6	10.0	5.0	2.0
2	2:38	3546	149	86	274	211.5	66		55	30.8	17.2	10.0	4.9	2.0
3	2:43	3588	150	84	272	211.5		51	55	30.0	17.0	9.8	4.8	1.9
4	2:48	3568	149	83	273	211.5			55	30.0	17.0	9.8	4.8	1.9
5	2:53	3560	149	80	274	211.5	67	50	55	30.0	17.0	9.9	4.8	1.9
6	2:58	3565	150	87	273	211.5			55	30.0	16.8	9.9	4.8	1.9
7	3:03	3548	149	80	274	211.5	67	50	55	30.0	16.8	9.8	4.8	1.9
8	3:08	3576	150	86	274	211.5			55	30.0	16.7	9.7	4.7	1.8
9	3:13	3574	150	82	271	211.5	65	51	55	30.0	16.6	9.7	4.7	1.8
10	3:18	3550	150	80	272	211.5			55	30.0	16.4	9.8	4.7	1.8
11	3:23	3537	148	87	274	211.5	68	52	55	30.0	16.5	9.8	4.7	1.8
12	3:28	3609	150	81	274	211.5			55	30.0	16.5	9.8	4.7	1.8
13	3:33	3590	150	87	274	211.5	69	52	55	30.0	16.5	9.8	4.7	1.8
Averages		3566	149.1	83.6	273	211.5	67	51	55	30.2	16.8	9.8	4.8	1.9

Steam Consumption 66.46 lb. Fr. Thermal Eff. 3.26% Fr. B. H. P. 14.82

Fr. Quality of Steam 98.2% Fr. Potential Eff. 22.3% Barometer 29.90"

Steam Economy and Efficiency Test of a 60HP Kerr Steam Turbine.

Steam Pressure 150 lb

$\frac{1}{2}$ Load.

Date: - Mch. 27, 09.

J.F. Weiss ^{Eng} H.E. Crisly.

No.	Time	A.P.M.	Col. Press.	Cond. Steam	Wt.	Temperatures				Stage Pressures.					
						Col.	Ex't	Inside	Outside	Enter	1	2	3	4	5
1	1:17	3588	150	0		264	212	66	52	91	52.0	30.5	18.5	9.9	
2	1:22	3567	148	128		261	212			91	52.0	30.8	18.8	10.1	4.0
3	1:27	3566	148	133		263	212	65	52	92	53.0	31.0	18.9	10.0	4.0
4	1:32	3570	148	131		266	212			92	53.2	31.2	19.0	10.1	4.0
5	1:37	3554	150	129		263	212	65	51	92	53.1	31.1	19.0	10.2	4.1
6	1:42	3567	148	126		262	212			95	54.0	31.5	19.0	10.1	4.1
7	1:47	3579	149	134		265	212	65	51	92	52.5	31.0	18.8	10.0	4.1
8	1:52	3579	149	130		264	212			92	53.0	31.0	19.0	10.0	4.0
9	1:57	3562	150	127		263	212	68	55	93	53.0	31.1	19.0	10.1	4.1
10	2:02	3572	150	133		263	212		52	94	53.5	31.5	19.1	10.2	4.2
11	2:07	3542	149	122		267	212	67	58	90	51.5	30.5	18.6	9.8	4.2
12	2:12	3577	148	127		264	212			89	51.0	29.6	18.2	9.6	4.0
13	2:17	3571	149	127		264	212	70	59	86	49.0	28.0	16.7	9.9	3.8
Averages		3568	149.4	128.9		264	212	66.6	53.6	91.5	52.4	30.7	18.7	10.0	4.0

Steam Consumption 51.06 lb.

Fr. Thermal Eff.

4.24%

Fr. B.H.P. 29.63

Fr. Quality of Steam 97.8%

Fr. Potential Eff. 29.0%

Barometer 28.92

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine. Steam Pressure 150 lb.

Date: - Mch. 27, 09

J.F. Weiss ^{3/4} Load.
or H.E.C. Cristy.

No.	Time	R.P.M.	Col. Press.	Wt. Cond. Steam	Temperatures				Stage Pressures.					
					Col.	Ex't	Inside	Outside	Enter.	1	2	3	4	5
1	11:47	3690	147	0	258	212.5	65	50	119	70.0	42.5	26.5	14.3	6.5
2	11:52	3688	148	177	261	212.5			117	69.0	42.6	26.0	14.1	6.5
3	11:57	3698	148	152	261	212.5	67	49	118	69.6	42.3	26.3	14.2	6.5
4	12:02	3679	149	170	260	212.5			119	70.0	42.5	26.5	14.3	6.6
5	12:07	3610	147	160	260	212.5	63	48	117	69.0	42.0	26.0	14.0	6.4
6	12:12	3617	149	164	259	212.5			119	70.0	42.5	26.5	14.3	6.6
7	12:17	3650	150	171	262	212.5	64	50	119	70.5	42.8	26.5	14.4	6.7
8	12:22	3638	148	170	263	212.5			119	69.9	42.2	26.3	14.3	6.6
9	12:27	3628	147	168	262	212.5	65	50	118	69.5	42.1	26.1	14.2	6.5
10	12:32	3568	144	167	263	212.5			116	68.0	41.6	25.8	13.8	6.3
11	12:37	3712	149	157	260	212.5	64	51	119	69.8	42.3	26.5	14.3	6.7
12	12:42	3605	148	150	259	212.5			119	69.9	42.4	26.5	14.3	6.6
13	12:47	3643	149	163	261	213.0	64	51	119	69.8	42.3	26.5	14.3	6.6
Averages		3649	147.8	164.1	261	212.5	64.6	49.9	118	69.6	42.3	26.3	14.2	6.5

Steam Consumption 42.37 lb.

Fr. Thermal Eff.

5.13%

Fr. B.H.P. 45.46

Fr. Quality of Steam 97.6%

Fr. Potential Eff.

36.1%

Barometer 28.96

Steam Economy and Efficiency Test of a 60 H.P. Kerr Steam Turbine. Steam Pressure 150 lb.

Date:- Jan. 2, 09.

J.F. Weiss ^{Eng} H.E. Christy.

No.	Time	R.P.M.	Cal.	Consid	Temperatures			Stage Pressures						
					Cal.	Ex't	Inside	Outside	Enter	1	2	3	4	5
1	4:38	3535	150	0	273	214	72.5	37	148	10.	24.2	35.5	56.0	88.5
2	4:43	3469	150	204	272	214	73.5	37	149	10	24	35.0	55.1	88.0
3	4:48	3667	150	203	272	214	74.0	37	149	10.1	24.	35.0	56.0	89.0
4	4:53	3555	150	204	273	214	62.0	37	148	10.	24.	34.7	54.8	88.0
5	4:58	3596	148	196	272	214	62.0	37	147	9.8	23.6	34.2	54.0	87.0
6	5:03	3620	152	207	267	214	61.0	37	151	10.2	23.7	36.0	57.0	90.0
7	5:08	3589	150	208	267	214	61.0	37	149	10.	23.7	35.1	56.0	88.7
8	5:13	3612	150	203	267	214	60.0	37	150	10.	23.5	35.0	55.0	88.3
9	5:18	3640	150	202	267	214	70.5	37	149	9.8	23.5	34.9	54.9	88.0
10	5:23	3520	150	206	270	214	70.5	37	150	10.	23.7	35.0	55.1	88.2
11	5:28	3735	150	202	268	214	73.0	37	150	10.	23.8	35.4	56.0	89.0
12	5:33	3607	150	200	267	214	74.0	37	149	9.9	24.	35.0	55.0	88.0
13	5:38	3543	150	204.	266	214	74.0	37	150	10.	24.2	35.4	55.4	88.7
Averages.		3591	150	203.3	269	214	68.3	37	149	10.0	23.8	35.1	55.6	88.5

Steam Consumption 40.7 lb.

Thermal Eff. 5.17%

W. B.H.P. 58.70

W. Quality of Steam .981

Potential Eff. 39.8%

Barometer 29.58"



COMPARATIVE EFFICIENCIES OF STEAM ENGINES
AND STEAM TURBINES IN SMALL UNITS

BY

HAROLD E CRISTY
LION GARDINER
WADE W REECE
JOHN FRANK WEISS

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE

IN MECHANICAL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

OF THE

UNIVERSITY OF ILLINOIS

Presented June, 1909

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COMPARATIVE EFFICIENCIES
OF
HIGH SPEED STEAM ENGINES AND STEAM TURBINES
IN SMALL UNITS.

PRELIMINARY REMARKS.

In large units the relative efficiency of the steam engine and the turbine as prime movers is comparatively well known, due to exhaustive tests under favorable conditions. In the case of smaller units this relationship is not so well established, and it is our purpose to determine which type, running under varying conditions of load and pressure, or under constant conditions, will give the best economical results. In the case of the small units, in the neighborhood of seventy-five horse power, the questions of floor space or of initial cost are not so important, so in the long run it is more a matter of reliability and economy of operation that makes one decide as to the prime mover best fitted for certain conditions. To obtain results bearing upon these questions is the ultimate purpose of this thesis.

DESCRIPTION OF ENGINE.

The prime mover tested in this case was an Ideal Engine rated at sixty horse power when running at 300 R.P.M. This engine is manufactured by A. L. Ide & Sons, of Springfield, Illinois, and is considered a good engine in its class. It is fitted with a fly-wheel inertia governor which automatically

cuts off steam supply or increases it, as the conditions call for. The governor and valve rod is shown in photograph on page 2a. Other details of the engine are:-

Horizontal.

Size cylinder 10" x 10".

Slide valve.

Length of connecting rod 2' 7".

Ratio of crank to connecting rod 1 to 6.

Diam.piston rod 1.5625".

Diam. fly wheel 4.55'.

Weight of fly wheel 800 lbs.

Velocity of rim 11.4 ft. per sec.

Splash lubrication.

OBJECT.

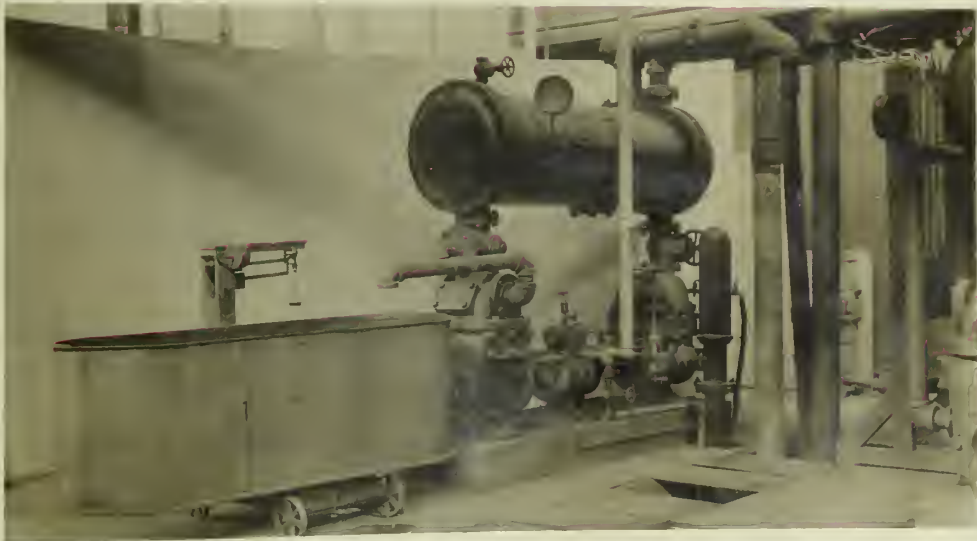
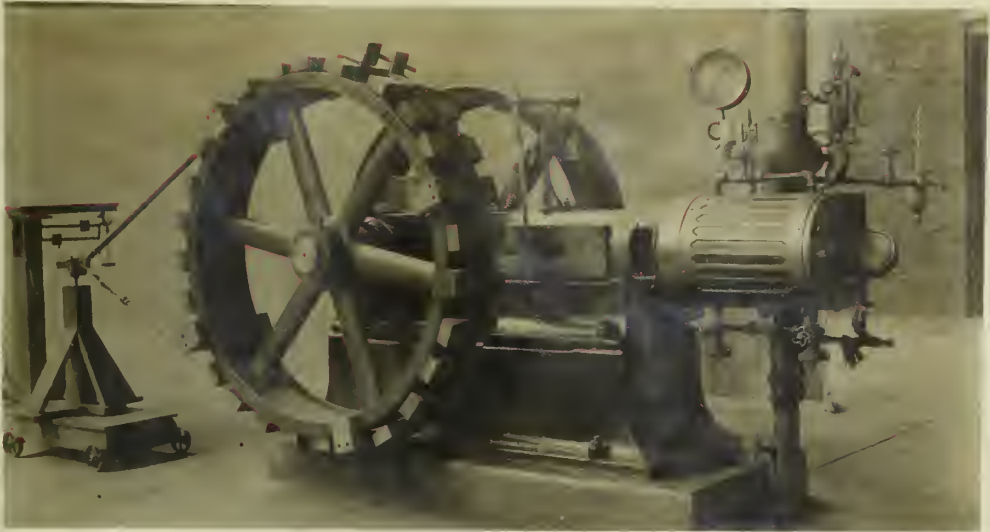
The purpose of this thesis is to obtain data from which a series of curves may be plotted that will fully show the relative performance of the steam engine and turbine working under the conditions of common practice. These comparisons are all to be made under the same conditions as to loads and pressures, so as to clearly point out the advantages, and points of advantage, of one over the other.

OTHER APPARATUS USED.

Wheeler Condenser. 75 H.P. capacity. 225 sq. ft. of surface. 6" - 8" - 8" - 7" combined air and circulating pumps.

Crosby Outside Spring Indicator.

Prony Brake. Arm - 5.25 ft.



Crosby High Pressure Steam Gage. 0 - 200 lbs.

Crosby Combination Low Pressure Gage.

Throttling Calorimeter.

Thermometer. 0 - 400 F.

Thermometer. 0 - 150 F.

Barometer.

Speed Indicator.

Platform Scales.

Tanks for weighing water.

METHOD OF CONDUCTING TEST.

In conducting these tests, in order that the range of conditions would be those of common practice, pressures of 100, 115, 130, 140, and 150# per sq. in. were used. To cover the varying conditions under each pressure, six tests were made with the following loads:- No load, 1/4, 1/2, 3/4, Full and 1-1/4. The tests were usually of about an hour and a half duration and from the results a set of data covering an hour's run was selected for final computations.

The exhaust from the engine was carried to a condenser and by means of a valve on the condenser, which opened to the atmosphere, the back pressure at the engine was kept in the neighborhood of one or two lbs., which is approximately the conditions of an engine running non-condensing and exhausting into the atmosphere through a suitable size exhaust pipe. The condensed steam, as it was withdrawn from the condenser by the pump, was collected in tanks and carefully weighed. All readings were taken at five minute intervals and from

instruments which had been calibrated with standards. The following readings were taken:-

Indicator cards.

Rev. per min.

Wt. on scales.

Steam pressure at throttle.

Steam pressure at exhaust.

Calorimeter temperature.

Wt. of condensed steam. (10 min. intervals).

Barometer reading	)	
Room temperature	)	at beginning of each test.

The load was kept constant by altering the tension in the prony brake band, and one person gave his whole attention to this during the tests.

The calorimeter was connected to the steam line just above the point where the steam entered the cylinder. Thus the condition of steam upon entering the engine was obtained. See cut page 20. The reducing mechanism for obtaining the indicator cards is shown in cut of the engine on page 2a. The steam pressure was kept approximately constant by throttling the pressure as it came from the main line into the header. This point of throttling was about ten feet from the engine cylinder.

The pull on the brake was measured on a pair of scales, allowance being made for the dead weight of the brake by subtracting the weight supported by the scales when the brake band was hung on a bar placed on the rim of the fly

wheel, vertically above the center, with the arm resting on the standard on the scales, in the regular operating position.

Before beginning test the "D" valve was taken off and faced and then adjusted so as to give equal work at full load to both sides of the piston. This setting was kept the same throughout the series of tests. The governor setting was also unaltered during the run.

DATA TO BE OBTAINED.

In general the comparison between the reciprocating engine and turbine is made on a basis of efficiencies, i. e., the relation of the heat put into useful work to the heat furnished the engine. In the case of the reciprocating engine the data to be obtained for these efficiencies is derived in the following manner:-

By use of the indicator, diagrams are obtained which represent the pressure acting in the cylinder at different stages of the stroke. The area of these diagrams being obtained by a planimeter, the mean ordinate is found by dividing the area of cycle by its length, and this length of mean ordinate in inches, multiplied by the scale of the indicator spring, gives the value of the mean effective pressure during the stroke. By substituting in the formula

$$\text{I.H.P.} = \frac{\text{PLAN}}{33000}$$

Where P = pressure in lbs. per sq. in. (mean effective)

L = length of stroke in feet.

A = area of piston in sq. in.

N = R.P.M.

The work done in each cycle is derived by adding the work of both crank and head end. The work of one revolution is thus obtained. These readings are taken every five minutes and the average of the readings gives the average indicated horse power which has been developed during the given period.

The actual horse power delivered by the engine is obtained by means of the prony brake. Force through distance represents work, so if the force exerted by the brake arm is measured, and also the distance through which it acts, the total work done can be derived. This force is measured in lbs. on the scales which carry the support of the brake arm. The distance through which this force acts can be calculated by knowing the length of the brake arm and the revolutions per minute of the fly wheel.

Substituting in the following formula

$$\text{B.H.P.} = \frac{2\pi RWN}{33000}$$

Where R = radius of brake arm in ft.

W = net weight on scales.

N = R.P.M.

the rate of doing work is obtained. These readings were taken every five minutes and their average gives the average brake horse power developed by engine during a given period.

The exhaust steam passing to the condenser is drawn into tanks and the amount of water weighed every ten minutes. The total weight of water for an hour's run is thus found, and dividing this weight by the horse power developed, the steam consumption per horse power hour is obtained.

The quality of steam entering the cylinder is calculated by use of the formula

$$X_2 = \frac{H_1 - q_2 + .48(T_s - T_1)}{L_2}$$

Where X_2 = quality of the steam

H_1 = total heat in a lb. of steam at T_1 .

q_2 = heat of liquid in a lb. of steam at steam line pressure.

L_2 = latent heat in a lb. of steam at steam line pressure.

.48 = spec. heat of superheated steam.

T_s = Temp. of steam in calorimeter.

T_1 = Temp. of steam at atmospheric pressure.

$(T_s - T_1)$ = Degree of superheat.

The quality of steam at exhaust cannot be actually derived, but approximate results may be obtained by the use of indicator diagrams and the actual steam flow.

Let $y\%$ = Clearance of engine.

V = Volume swept through by piston in cu. ft.

p = Absolute pressure at exhaust.

c = Spec. wt. of steam at exhaust pressure per cu. ft.

$z\%$ = $\frac{\text{Length of stroke at exhaust}}{\text{Total length of stroke.}}$

$V(y\% + z\%)$ = Total volume of cylinder at exhaust.

Then

$2 V(y\% + z\%) \times c \times \text{RPM}$ = Wt. of dry steam passing through cylinder per min. considering the space taken up by moisture as negligible.

$\frac{\text{Wt. dry steam} \times 60}{\text{Wt. steam flow per hr.}}$ = % quality of steam at exhaust.

As a result of several calculations at different loads and pressures, the following average values were used throughout all calculations:-

$$X_2 = 66\% \text{ for } \begin{pmatrix} (1-1/4) \\ \text{full} \\ (3/4) \end{pmatrix} \text{ loads.}$$

$$X_2 = 63\% \text{ for } 1/2 \text{ load.}$$

$$X_2 = 60\% \text{ for } \begin{pmatrix} (1/4) \\ \text{No} \end{pmatrix} \text{ loads.}$$

With the above data at hand the following basis of efficiencies are used:-

$$\text{Mechanical Eff.} = \frac{\text{B.H.P.}}{\text{I.H.P.}}$$

which is the ratio of the work done in the cylinder to work done by the engine.

$$\text{Thermal Eff.} = \frac{2545 \text{ BTU}}{W(q_1 + X_1 L_1)}$$

$$W = \text{lbs. per B.H.P. hr.}$$

$(q + XL)$ = heat per lb. steam at gage pressure, which is the relation of the heat developed in the form of work to the heat supplied to the engine.

$$\text{Thermodynamic Eff.} = \frac{2545 \text{ B.T.U.}}{W[(q_1 + X_1 L_1) - (q_2 + X_2 L_2)]}$$

$$W = \text{lbs. per I.H.P. hr.}$$

$$(q_1 + X_1 L_1) = \text{heat per lb. steam gage pressure.}$$

$$(q_2 + X_2 L_2) = \text{heat per lb. steam exhaust pressure.}$$

which gives the ratio of the heat developed in the form of work in the cylinder to the heat consumed in the cylinder.

$$\text{Potential Eff.} = \frac{2545 \text{ B.T.U.}}{W[(q_1 + X_1 L_1) - (q_2 + X_2 L_2)]}$$

$W = \text{lbs. per B.H.P. hr.}$

$(q_1 + X_1 L_1) = \text{heat per lb. steam gage pressure.}$

$(q_2 + X_2 L_2) = \text{heat per lb. steam exhaust pressure.}$

which is the ratio of the heat developed in the form of work to heat consumed in the cylinder.

SAMPLE CALCULATIONS.

Sample calculations follow of reading No. 1 of test No. 5 at 130 lbs. pressure, but in figuring the thermal, thermodynamic and potential efficiencies the average readings of the whole test are taken. In obtaining the water rate per I.H.F. hr. and per B.H.P. hr. the average of the I.H.P. and B.H.P. results and the total steam consumption will be the basis of calculations.

We have

$$\text{B.H.P.} = \frac{2\pi RNP}{33000} = \frac{2\pi R}{33000} \times NP$$

in which R is the length of the prony brake arm, in this case 5' 3". N is the R.P.M. of engine and P is the pull in pounds exerted by the brake arm. It will be seen that N and P are variable, and, the other terms being constant, we have

$$\text{B.H.P.} = \frac{2 \times 3.14 \times 5.25}{33000} \times NP = .001 NP$$

The governor having been set for 300 R.P.M., the weight P on scales for different loads is as follows:-

$$1/4 \text{ load } P = \frac{15}{.001 \times 300} = 50 \text{ lbs.}$$

$$1/2 \text{ load } P = \frac{30}{.001 \times 300} = 100 \text{ lbs.}$$

$$3/4 \text{ load } P = \frac{45}{.001 \times 300} = 150 \text{ lbs.}$$

$$\frac{3}{4} \text{ load } P = \frac{45}{.001 \times 300} = 150 \text{ lbs.}$$

$$1 \text{ load } P = \frac{60}{.001 \times 300} = 200 \text{ lbs.}$$

$$1\text{-}1/4 \text{ load } P = \frac{75}{.001 \times 300} = 250 \text{ lbs.}$$

The engine constant for the I.H.P. is found as follows:-

Head end:

$$\text{I.H.P.} = \frac{PLAN}{33000} = PN \times C.$$

$$P = \text{M.E.P.}$$

$$N = \text{R.P.M.}$$

$$L = \text{Length of stroke in feet.}$$

$$A = \text{Area of cylinder in sq. inches.}$$

$$\text{I.H.P.} = PN \times \frac{10 \times 3.14 \times 10^2}{12 \times 4 \times 33000} = .001983 PN.$$

Crank end:

$$\text{I.H.P.} = \frac{FLAN}{33000}$$

In which A = area cylinder in sq. in. - area of piston rod.

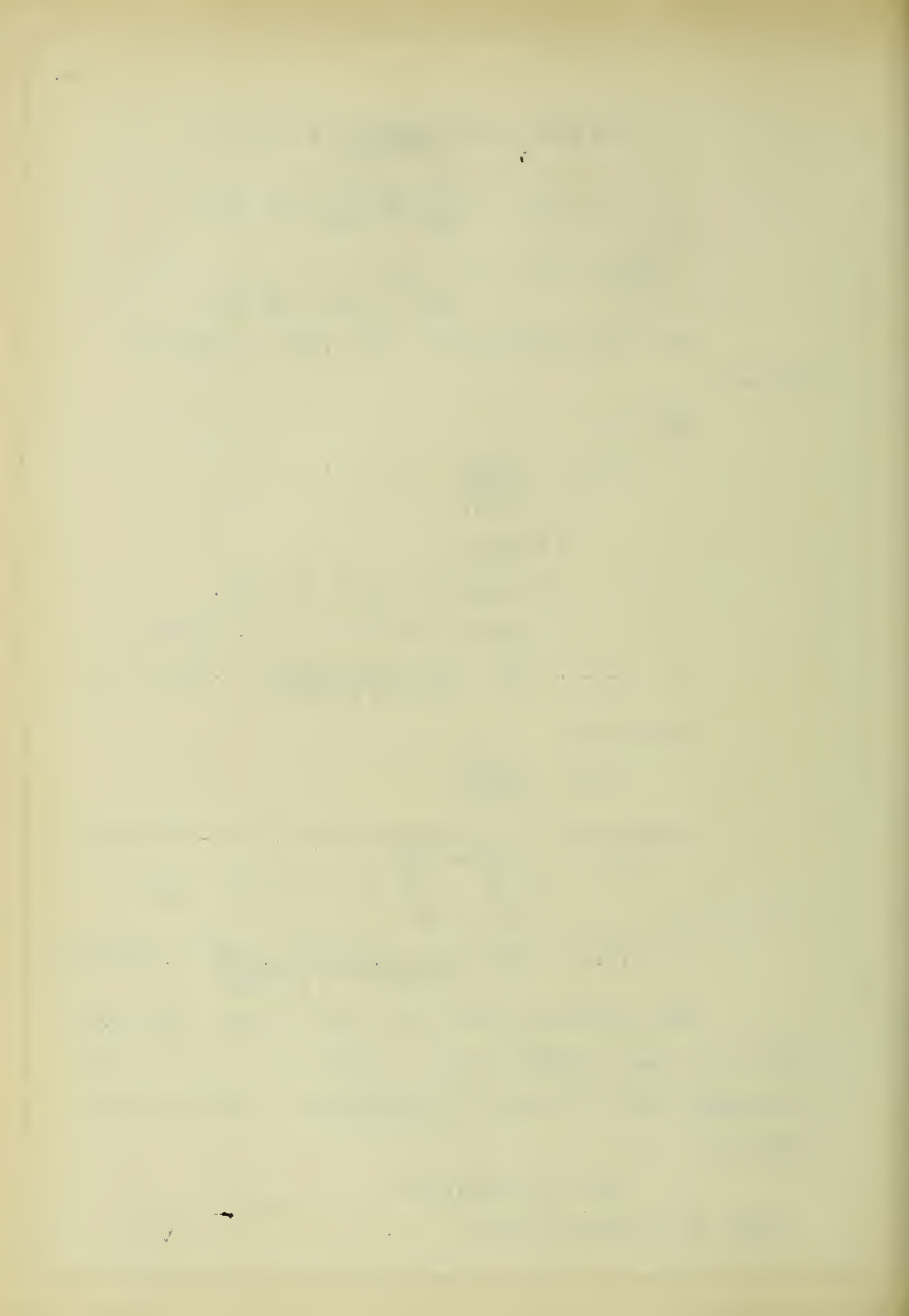
$$= \frac{D^2}{4} - \frac{d^2}{4} \quad d = 1\text{-}9/16" = 1.56".$$

$$\text{I.H.P.} = PN \times \frac{10 \times 3.14(10^2 - 1.56^2)}{12 \times 4 \times 4 \times 33000} = .001934 PN.$$

The following method was used to obtain the M.E.P.
Taking card #4, on 150# pressure, page 14b, the area of each diagram was found by means of a planimeter. In the case of head end:-

$$\text{Area} = 1.35 \text{ sq. in.}$$

$$\text{Length of Diagram} = 3.52".$$



$$\text{Mean Ord.} = 1.35 \div 3.52 = .385 \text{ in.}$$

$$\text{Scale of spring} = 120.6 \text{ lbs.}$$

$$.385 \times 120.6 = .46.45 \text{ lbs. per sq. in. or M.E.P.}$$

Reading #1, test #5, 130# pressure:

$$\text{B.H.P.} = .001 \times 298 \times 200 = 59.6.$$

Head end:

$$\text{I.H.P.} = .001934 \times 56.9 \times 298 = 33.65.$$

Crank end:

$$\text{I.H.P.} = .001934 \times 54.9 \times 298 = 31.62.$$

Efficiencies:-

$$\text{Mech. Eff.} = \frac{\text{B.H.P.}}{\text{I.H.P.}} = \frac{59.6}{65.27} = 91.5\%.$$

The thermal efficiency is the ratio of the heat equivalent of the work developed to the heat supplied to the engine.

$$\text{Thermal Eff.} = \frac{2545}{W(q_1 + x_1 L_1)}$$

Where W = steam consumption per B.H.P. hr.

q = heat of liquid.

x = quality of steam.

L = latent heat of steam.

In the test under consideration the atmospheric pressure = $130.7 + 14.42 = 145.1$ or P. From Peabody's steam tables at this pressure

$$q = 327.3$$

$$L = 863$$

$$\text{Then thermal eff.} = \frac{2545}{41.4(327.5 + .9952 \times 863)}$$

$$= 4.75\%.$$

The thermodynamic efficiency is the ratio of the heat equivalent of the work developed in the cylinder to the heat consumed in the cylinder.

$$\text{Thermodynamic eff.} = \frac{2545}{W_1(q_1 + x_1 L_1 - q_2 - x_2 L_2)}$$

In which W = steam consumption per I.H.P. hr.

Subscripts 1 and 2 refer to entering and leaving conditions.

$$\begin{aligned} \text{Thermodynamic Eff.} &= \frac{2545}{45.23(327.3 + .9952 \times 863 - 18.23 - .66 \times 964.9)} \\ &= 16.88\%. \end{aligned}$$

The potential efficiency is the ratio of the heat developed in the form of work to the amount of heat consumed in the cylinder.

$$\text{Potential Eff.} = \frac{2545}{W(q_1 + x_1 L_1 - q_2 - x_2 L_2)}$$

W = steam consumption per B.H.P. hr.

Subscripts 1 and 2 refer to entering and leaving conditions.

$$\begin{aligned} &= \frac{2545}{41.4(327.3 + .9952 \times 863 - 182.3 - .66 \times 964.9)} \\ &= 15.41\%. \end{aligned}$$

Water rates:

$$\text{Steam consumption per I.H.P. hr.} = \frac{\text{total wt. of steam used per hr.}}{\text{I.H.P. hr.}}$$

$$\text{Steam consumption per B.H.P. hr.} = \frac{\text{total wt. of steam used per hr.}}{\text{B.H.P. hr.}}$$

The quality of steam entering the cylinder was obtained from Peabody's steam tables, knowing the absolute pressure and the superheat. These tables were derived from the equation given on page 7.

The quality of steam in the exhaust was obtained by use of the indicator diagrams. See Fig.4 Page 14 b.

Head end:

$$\frac{2.48}{3.52} = 70.5\% \text{ of vol. release.}$$

$$.455 \times 70.5 = .321 \text{ cu. ft.}$$

$$.321 \quad .036 = .357 \text{ cu. ft.}$$

Aver. R.P.M.

$$.357 \times .1297 \times 297 \times 60 = 818 \text{ lbs.}$$

$$.455 \text{ cu. ft.} = \text{vol. swept through by piston.}$$

$$.455 \times 8\% = .036 \text{ cu. ft. clearance.}$$

$$55\# = \text{ab. press. at exhaust.}$$

$$\text{From tables spec. density} = .1297.$$

Crank end:

$$\frac{2.45}{3.52} = 69.5\% \text{ of vol.}$$

$$.455 \times 69.5 = .316.$$

$$.352 \times .1186 \times .294 \times 60 = 736 \text{ lbs.}$$

$$50\# = \text{ab. pressure at exhaust.}$$

$$.1186 = \text{density.}$$

$$\text{Total steam per hr.} = 736 \quad 818 = 1554 \text{ lbs.}$$

$$\text{Actual steam per hr. by weight} = 2350.$$

$$\frac{1554}{2350} = 66\% \text{ quality of steam at exhaust.}$$

20

SAMPLE INDICATOR CARDS.

The following cards are typical of the tests run, one card being taken for each load. See page 14a, 14b.

It will be noticed that as the load increases the back pressure in the cylinder increases. This is due to the additional amount of steam used, which must leave the cylinder through the same valve, and in the same length of time as at light load. This back pressure, while not excessive, tends to reduce the work done and the remedy would be larger exhaust ports. This back pressure is also caused by defective design in the case of inlet and outlet pipes, both of which are the same size.

No Load 115# Pressure.

Scale Spring = 80#

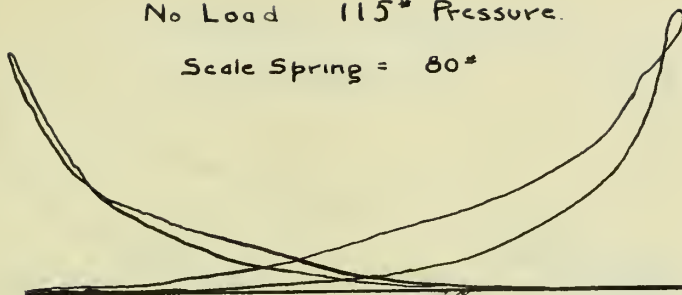


Figure 1.

$\frac{1}{4}$ Load 100# Pressure

Scale Spring = 80#

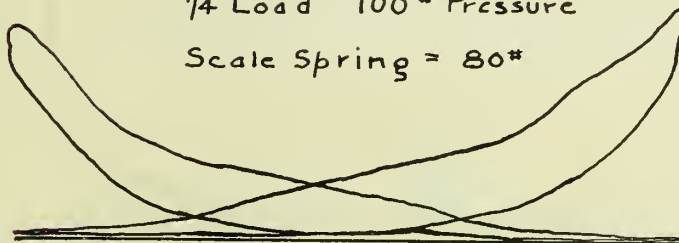


Figure 2.

$\frac{1}{2}$ Load 130# Pressure

Scale Spring = 120#



Figure 3.

Area diag. = .135 sq. in.

Mean Ord. = .385 in.

M.E.P. = 46.45 lbs.

I.H.P. = 27.21

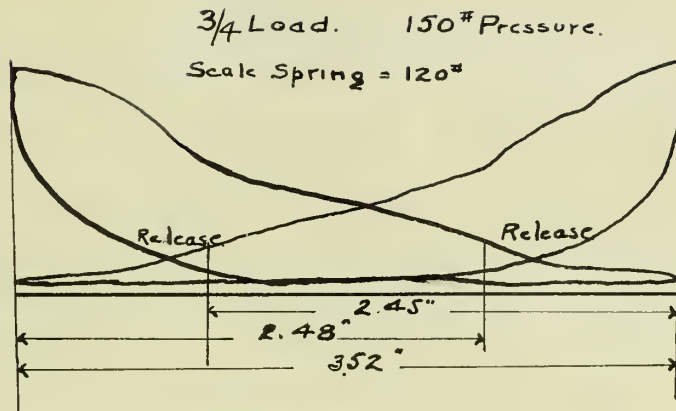


Figure 4.

Full Load. 150# Pressure.
Scale Spring = 120#

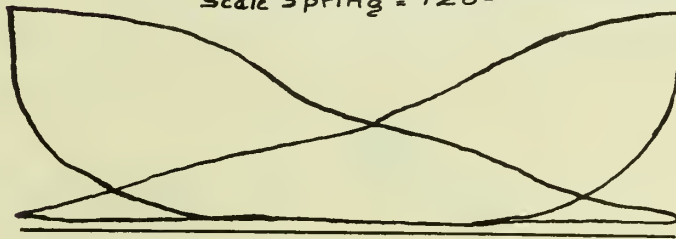


Figure 5.

1 1/4 Load 140# Pressure.
Scale Spring = 120#

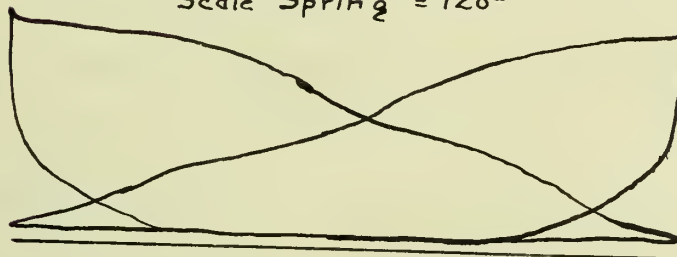


Figure 6.

CONCLUSIONS.

a. Steam consumption.

The steam consumption of the turbine is at all loads less than that of the engine, although at $3/4$ and full loads the difference is much less, and were the curves to be extended further, the indications are that at $1-1/4$ load the consumption would be approximately the same. The varying pressures do not seem to make much difference in the consumption of the turbine. The engine uses the least steam at 115 lbs. pressure and increases above that point. This is possibly due to the leakage in the steam chest which would naturally increase with an increase of pressure. The turbine rate is relatively less at the low loads.

b. Thermal Efficiency.

The thermal efficiency of the turbine is approximately the same at all pressures when $3/4$ load is being carried. Below this load the lower pressures show to advantage and above this load the high pressures give best efficiencies. The maximum efficiency comes at 150# pressure and full load.

In the case of the engine the same results are obtained except that the turbine efficiency is higher. The difference is more noticeable at low loads and at full load and load and a quarter the efficiencies are nearly the same, the turbine average, however, is higher.

c. Potential efficiencies.

Again in both the engine and turbine the low pressures show to better advantage than the high pressures

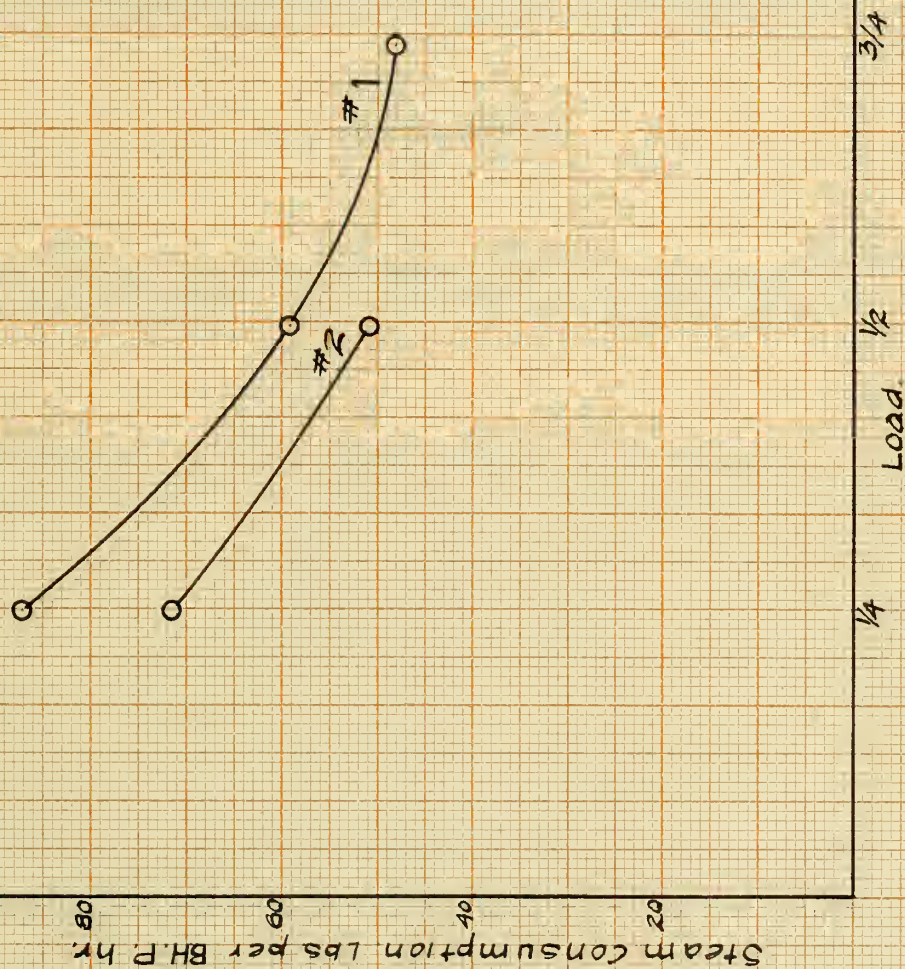
when the load is below $3/4$ s, but above this point the conditions are reversed. In the case of the engine all are about equal at 60 H.P. The potential efficiency increases with the load more rapidly in the case of the turbine and this curve is above that of the engine at all times.

The above results would indicate that for a prime mover carrying a varying load the turbine would be much more efficient, but where the load was constantly full, or above, the difference would be very slight.

Note:-

The data for the turbine performance was taken from the thesis of J. F. Weiss and H.E. Cristy 1909. "Comparative Efficiencies of High Speed Steam Engines and Steam Turbines in Small Units."

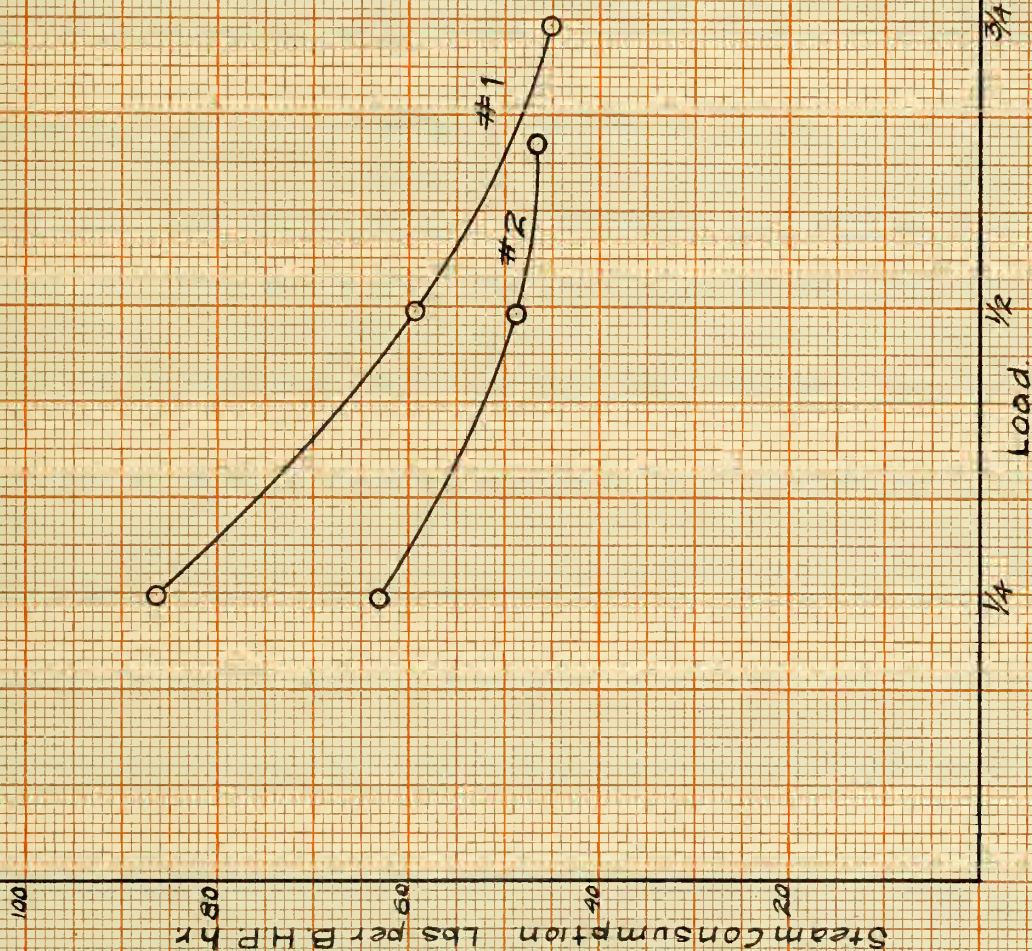
CURVES SHOWING RELATION
 BETWEEN STEAM CONSUMPTION
 IN LBS. PER B.H.P.Hr. AND LOAD
 FOR A 60 H.P. STEAM ENGINE.
 AND A 60 H.P. STEAM ENGINE.
 LINE PRESS. — 100 LBS.
 #1 — ENGINE.
 #2 — TURBINE.



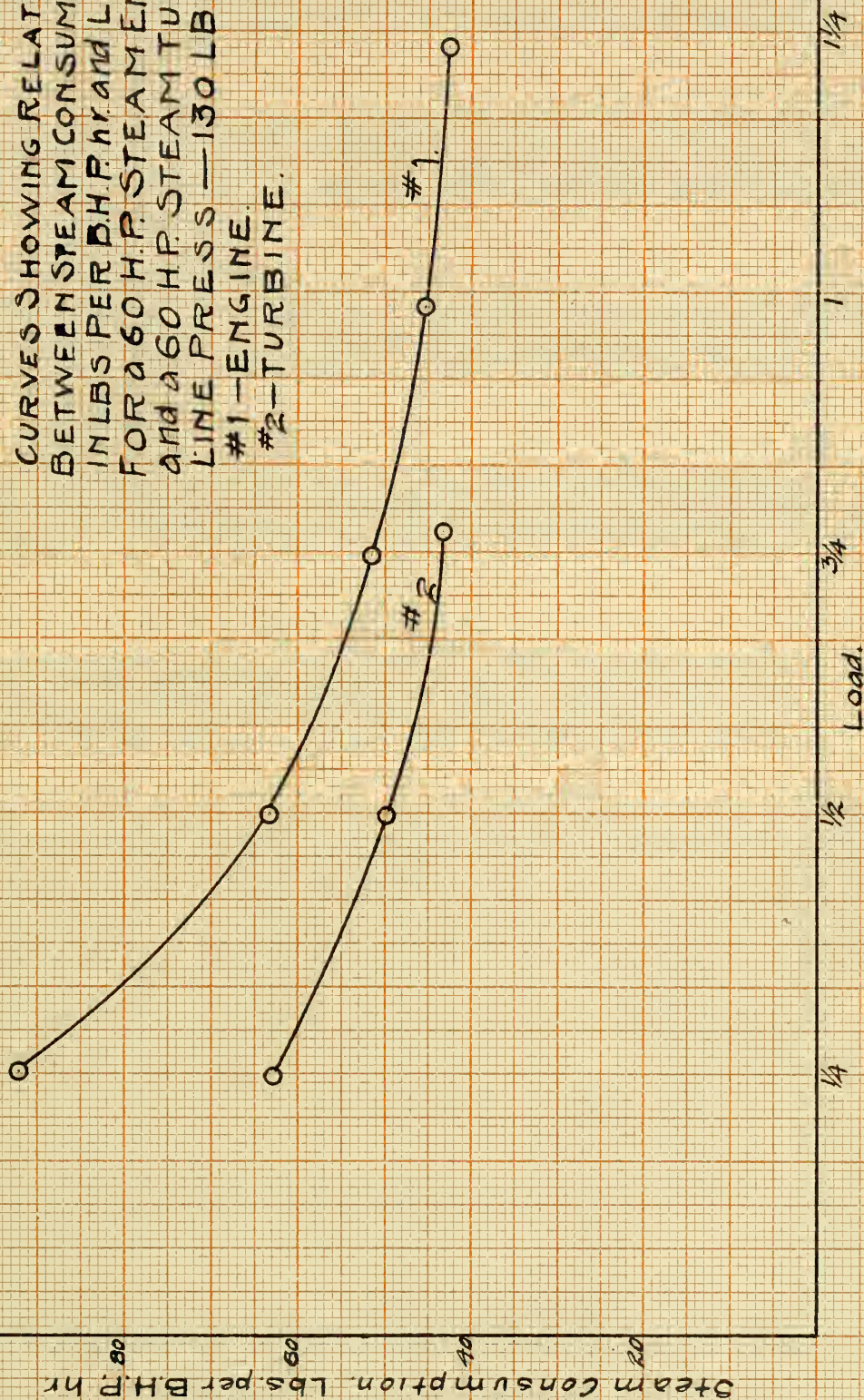
CURVES SHOWING RELATION
BETWEEN STEAM CONSUMPTION
IN LBS. PER B.H.P.HR AND LOAD
FOR A 60 H.P. STEAM ENGINE
AND A 60 H.P. STEAM TURBINE.
LINE PRESS—115 LBS.

#1 — ENGINE

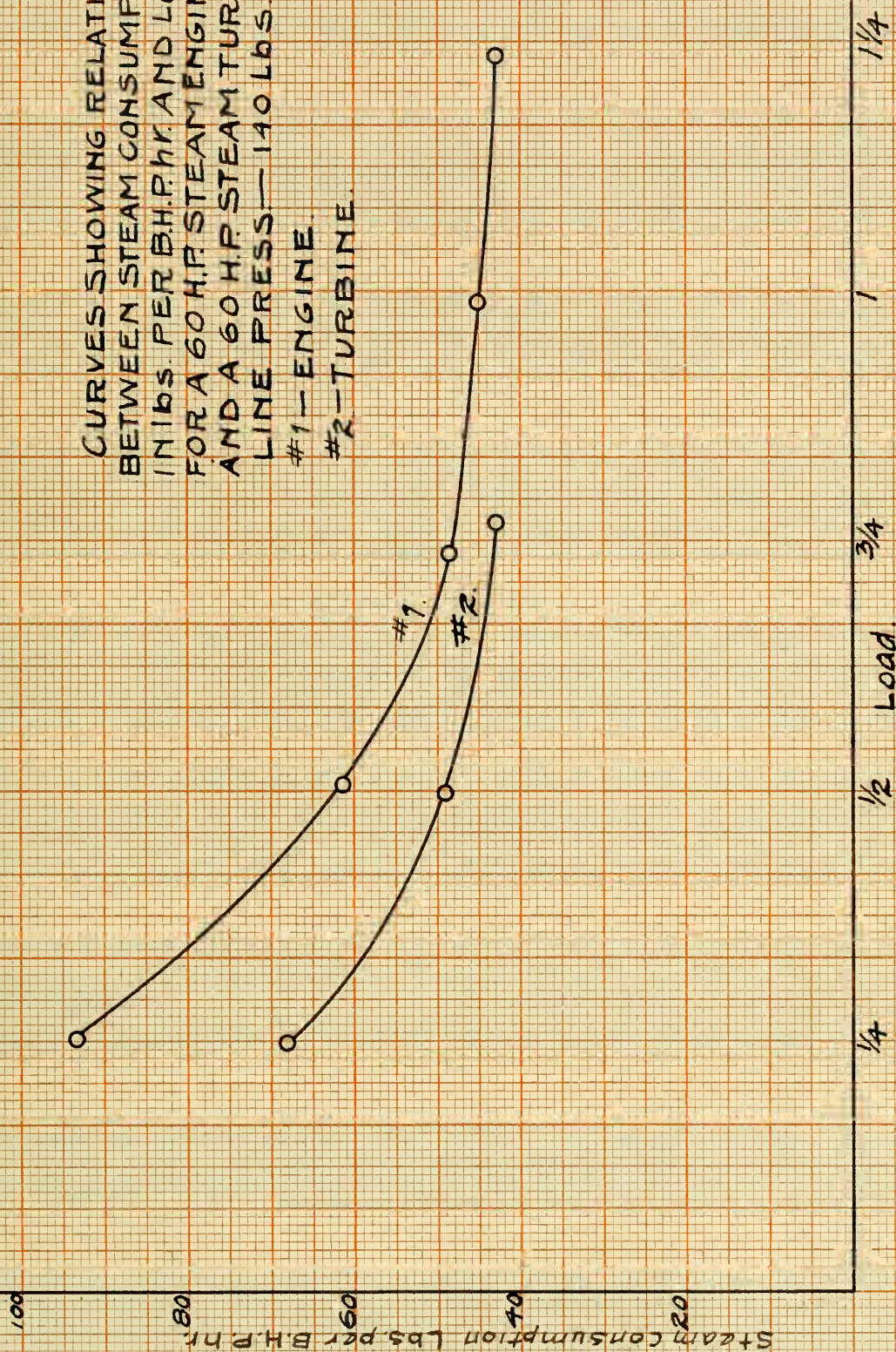
#2 — TURBINE



CURVES SHOWING RELATION
BETWEEN STEAM CONSUMPTION
IN LBS PER B.H.P. AND LOAD
FOR A 60 H.P. STEAM ENGINE
AND A 60 H.P. STEAM TURBINE.
LINE PRESS — 130 LBS.
#1 — ENGINE.
#2 — TURBINE.



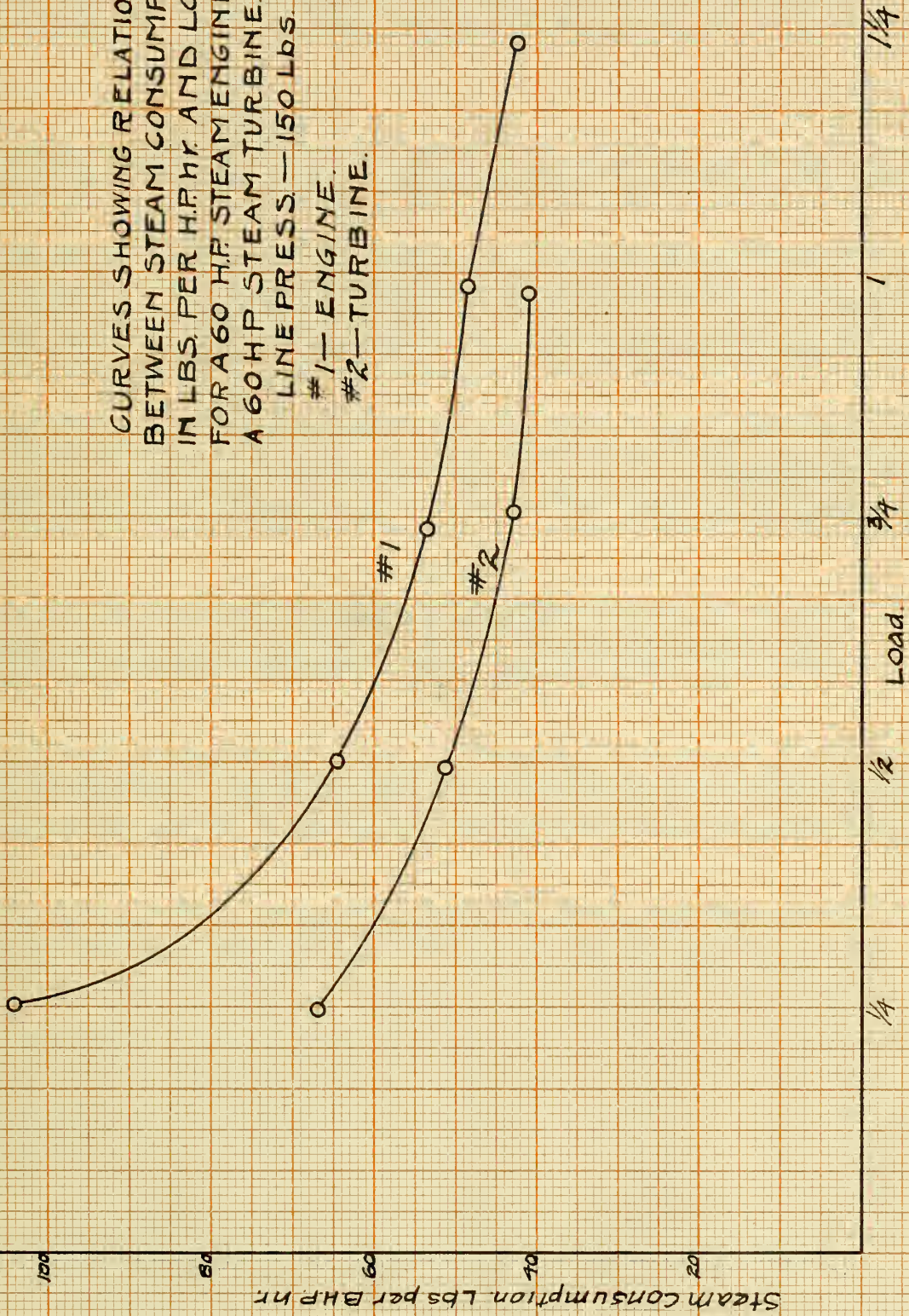
CURVES SHOWING RELATION
 BETWEEN STEAM CONSUMPTION
 IN LBS. PER B.H.P.HR. AND LOAD
 FOR A 60 H.P. STEAM ENGINE
 AND A 60 H.P. STEAM TURBINE.
 LINE PRESS.—140 LBS.
 #1—ENGINE.
 #2—TURBINE.



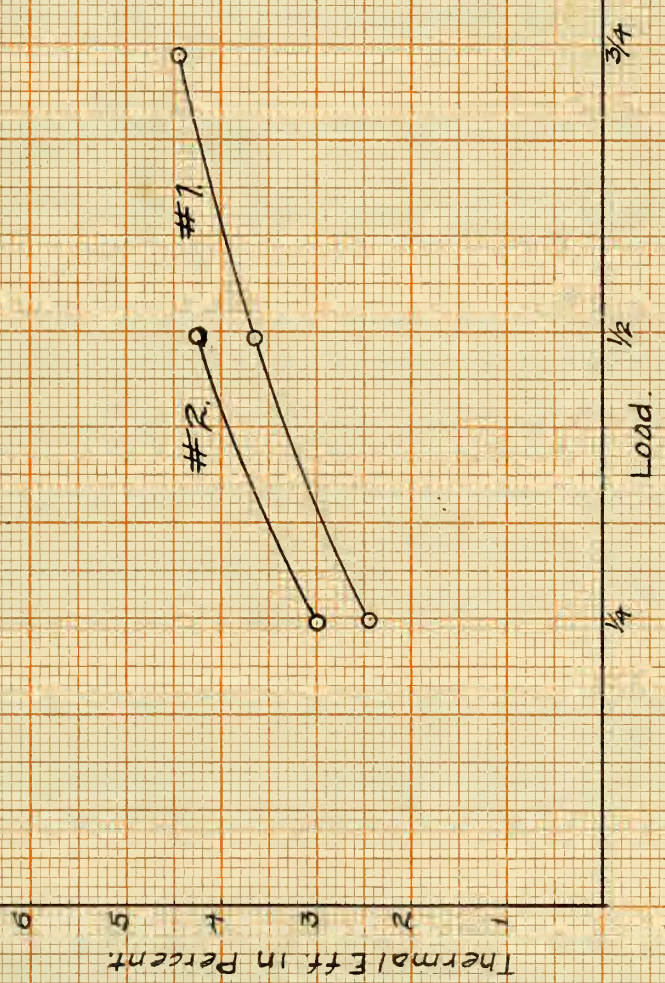
CURVES SHOWING RELATION
BETWEEN STEAM CONSUMPTION
IN LBS. PER H.P.HR. AND LOAD
FOR A 60 H.P. STEAM ENGINE AND
A 60 H.P. STEAM TURBINE.
LINE PRESS. — 150 LBS.

#1 — ENGINE.

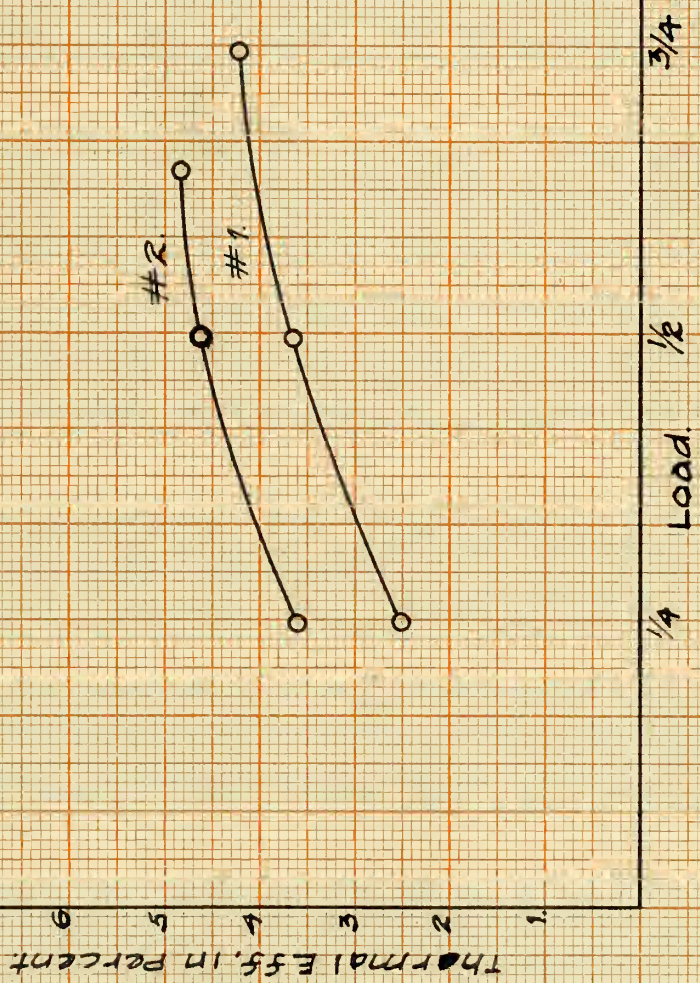
#2 — TURBINE.



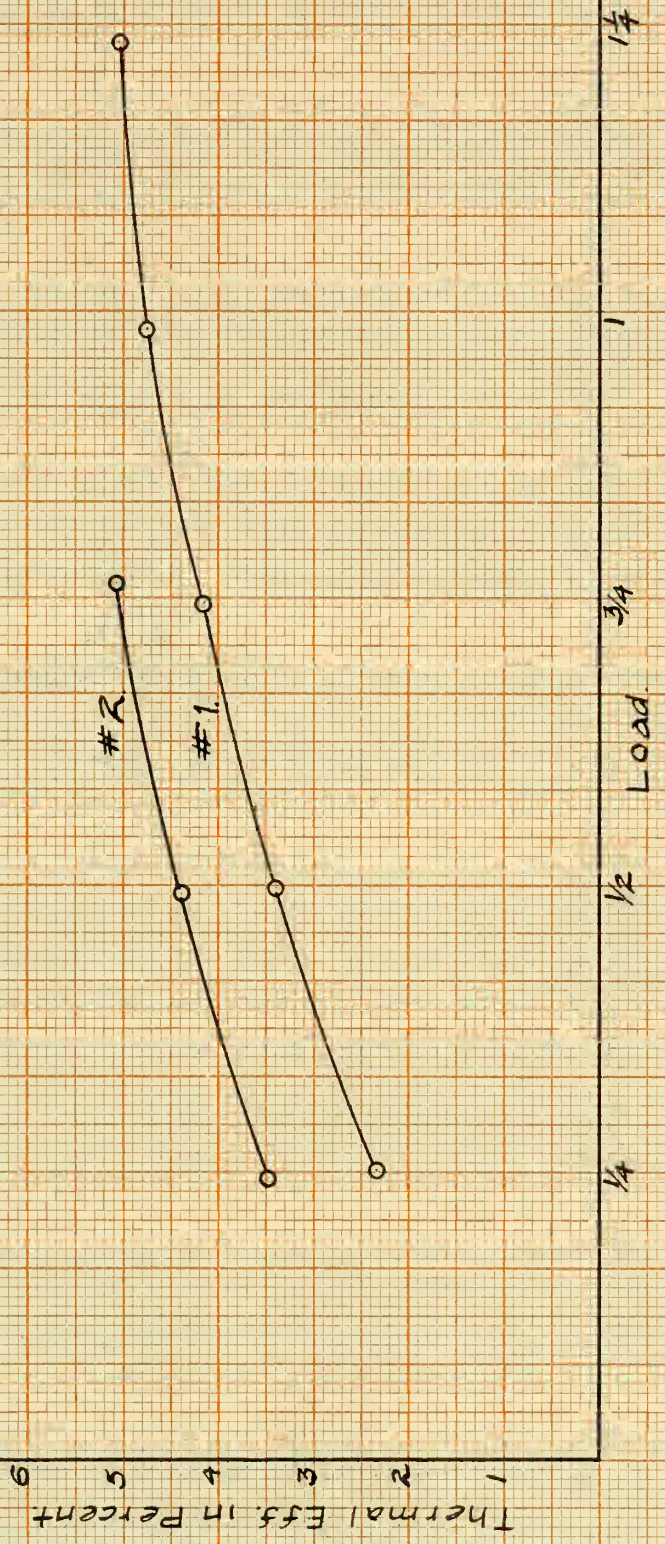
CURVES SHOWING RELATION
BETWEEN THERMAL EFF AND
LOAD FOR A 60 H.P. STEAM ENGINE
AND A 60 H.P. STEAM TURBINE.
LINE PRESS. - 100 LBS.
#1 - ENGINE.
#2 - TURBINE.



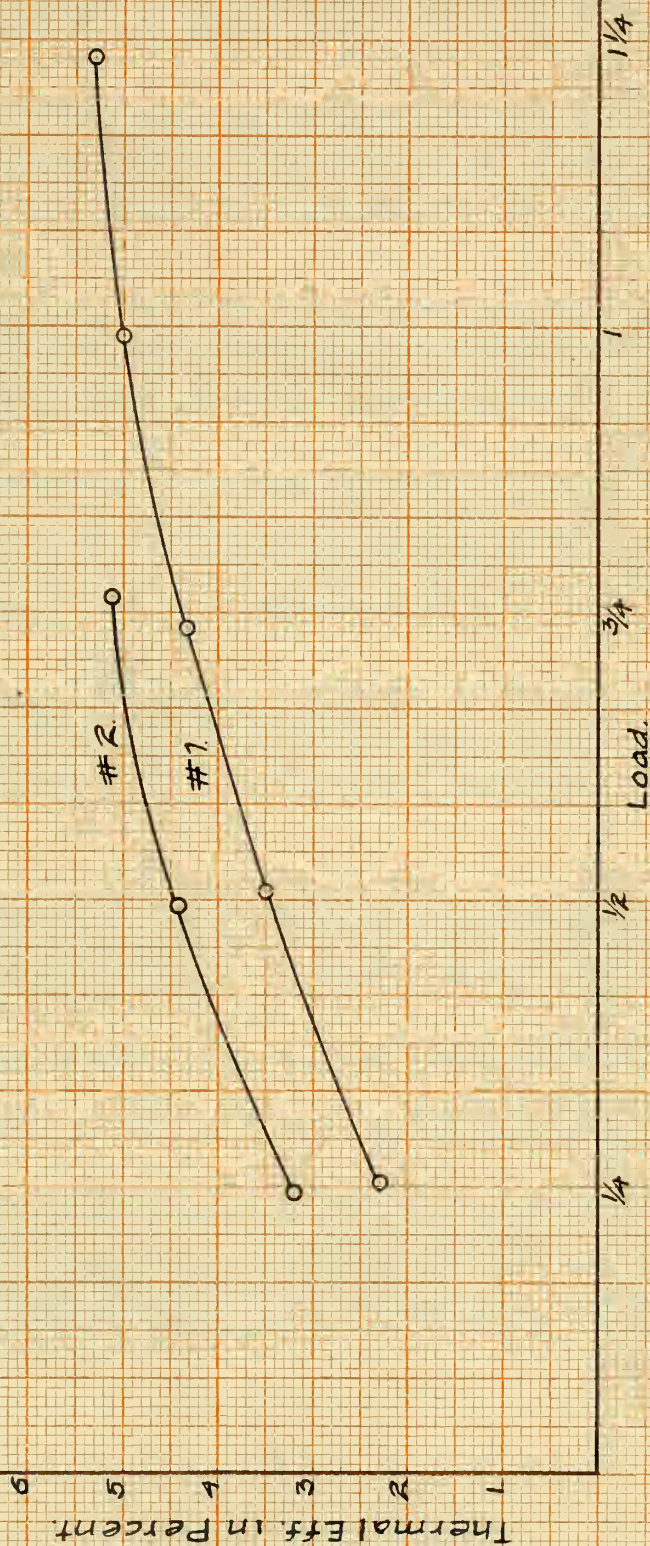
CURVES SHOWING RELATION
 BETWEEN THERMAL EFF. AND
 LOAD FOR A 60 H.P. STEAM ENGINE
 AND A 60 H.P. STEAM TURBINE.
 LINE PRESS - 115 LBS.
 #1 - ENGINE.
 #2 - TURBINE.



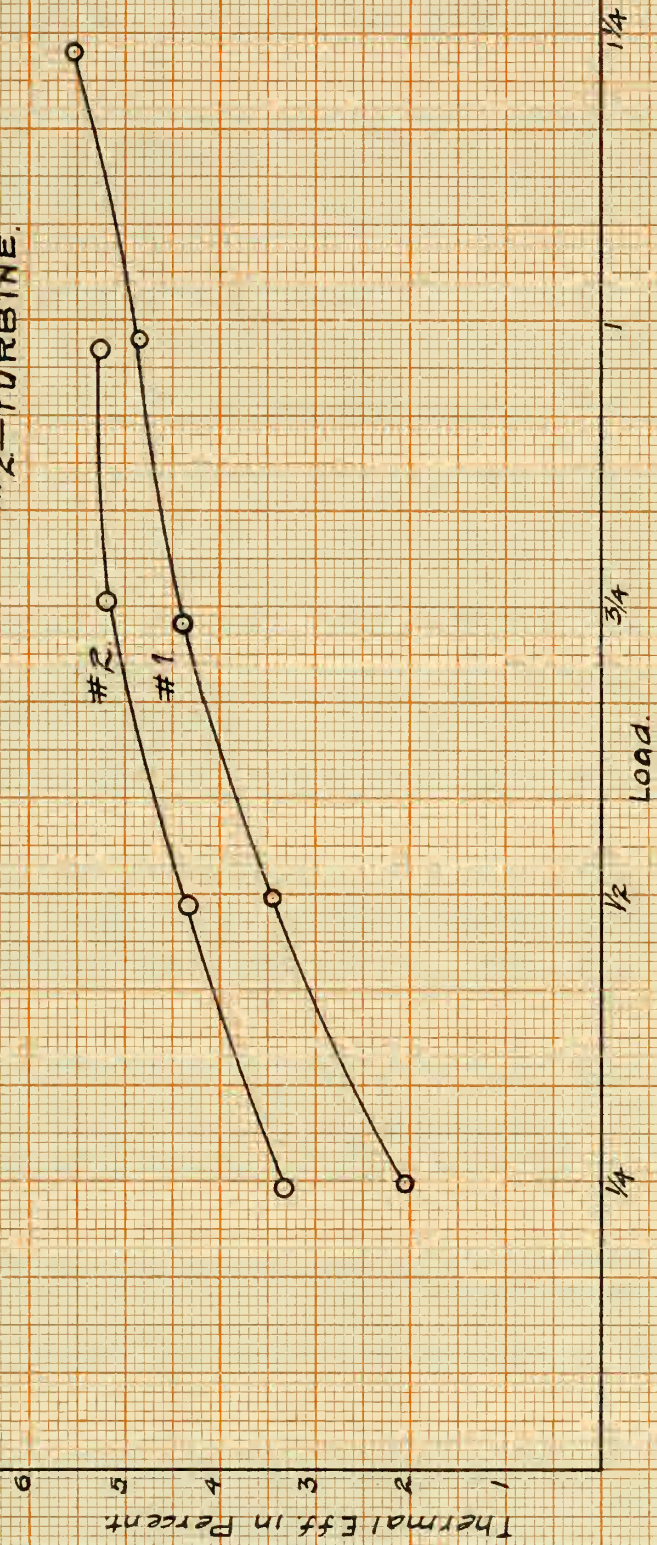
CURVES SHOWING RELATION
BETWEEN THERMAL EFF. AND
LOAD FOR A 60 H.P. STEAM ENGINE
AND A 60 H.P. STEAM TURBINE.
LINE PRESS. - 130 LBS.
#1 - ENGINE.
#2 - TURBINE.



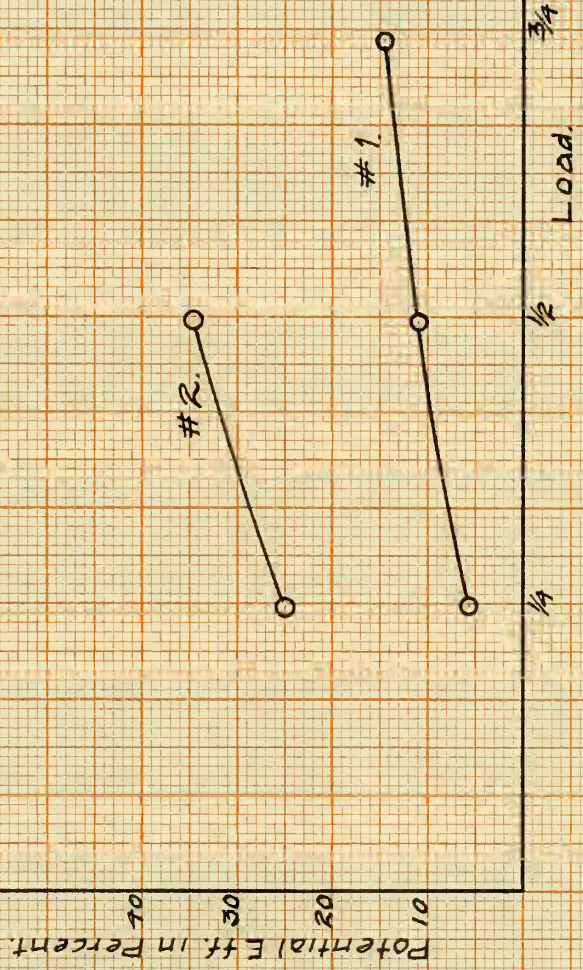
CURVES SHOWING RELATION
BETWEEN THERMALEFF AND
LOAD FOR A 60 H.P. STEAM ENGINE
AND A 60 H.P. STEAM TURBINE.
LINE PRESS. - 140 LBS.
#1 - ENGINE.
#2 - TURBINE.



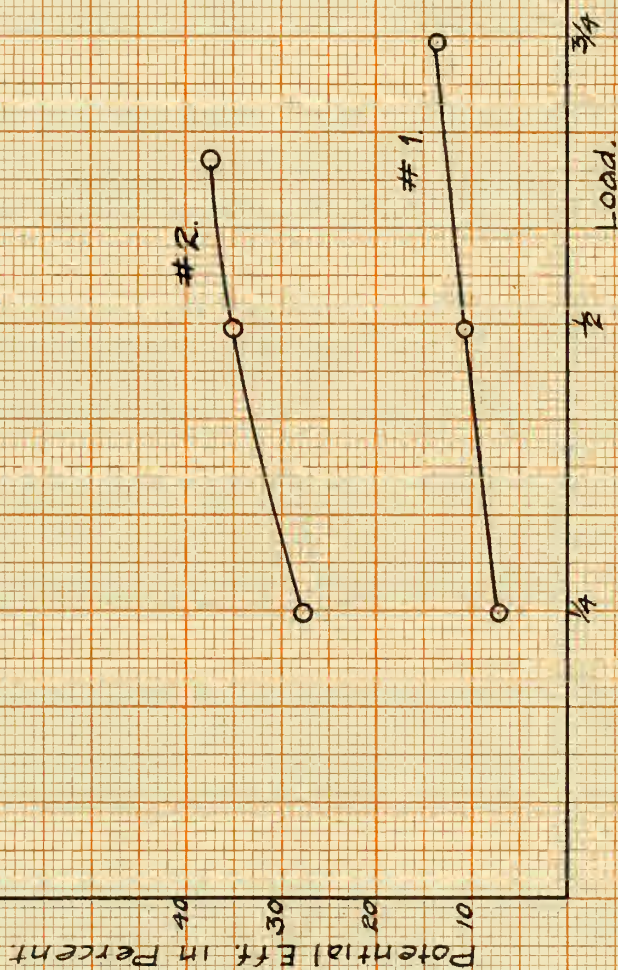
CURVES SHOWING RELATION
BETWEEN THERMAL EFF. AND
LOAD FOR A 60 H.P. STEAM ENGINE
AND A 60 H.P. STEAM TURBINE.
LINE PRESS. - 150 LBS.
#1 - ENGINE.
#2 - TURBINE.



CURVES SHOWING RELATION
BETWEEN POTENTIAL EFF AND
LOAD FOR A 60 H.P. STEAM ENGINE
AND A 60 H.P. STEAM TURBINE.
LINE PRESS.— 100 LBS.
#1—ENGINE
#2—TURBINE.



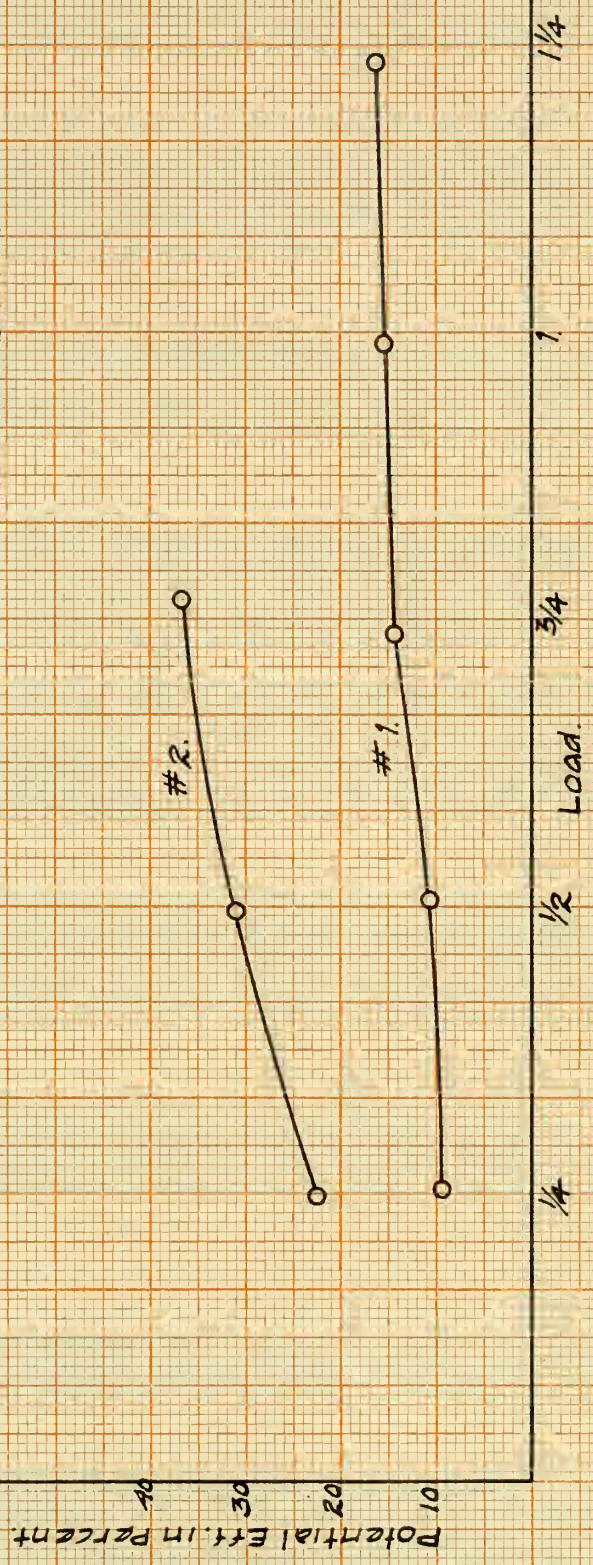
CURVES SHOWING RELATION
BETWEEN POTENTIAL EFF. AND
LOAD FOR A 60 H.P. STEAM ENGINE
AND A 60 H.P. STEAM TURBINE.
LINE PRESS. — 115 LBS.
#1 — ENGINE
#2 — TURBINE.



CURVES SHOWING RELATION
BETWEEN POTENTIAL EFF. AND LOAD
FOR A 60 H.P. STEAM ENGINE AND
A 60 H.P. STEAM TURBINE.
LINE PRESS. - 130 LBS.
#1 - ENGINE.
#2 - TURBINE.

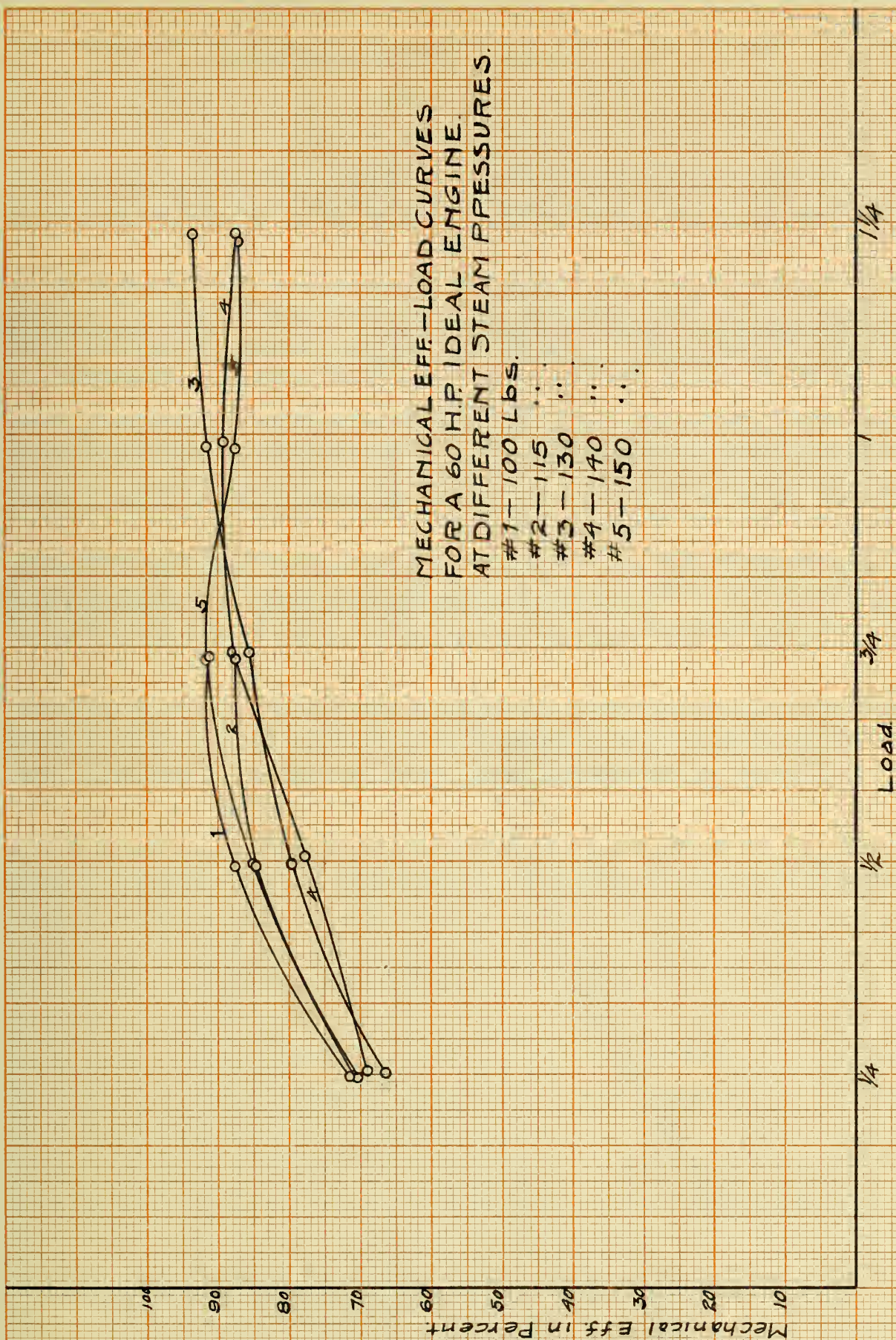


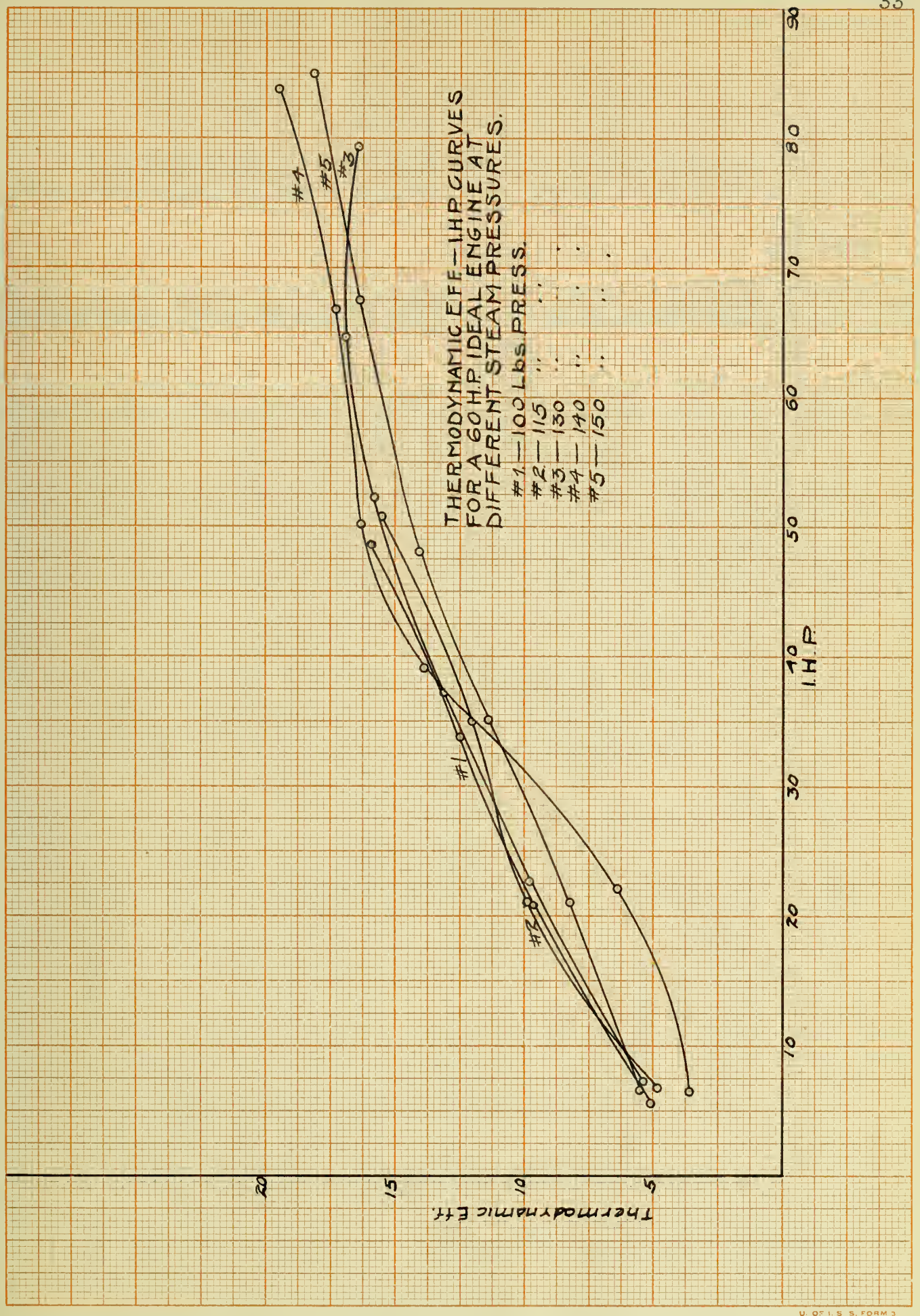
CURVES SHOWING RELATION
BETWEEN POTENTIAL EFF. AND
LOAD FOR A 60 H.P. STEAM ENGINE
AND A 60 H.P. STEAM TURBINE.
LINE PRESS. - 140 LBS.
#1 - ENGINE.
#2 - TURBINE.



CURVES SHOWING RELATION
BETWEEN POTENTIAL EFF. AND
LOAD FOR A 60 H.P. STEAM ENGINE
AND A 60 H.P. STEAM TURBINE.
LINE PRESS.—150 LBS.
#1—ENGINE.
#2—TURBINE.







Thermodynamic Eff. - I.H.P. Curves
for a 60 H.P. ideal engine at
different steam pressures.
#1 - 100 lbs. press.
#2 - 115
#3 - 130
#4 - 140
#5 - 150

UNIV. OF ILLINOIS. MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure

100 Mechanical Eff.

Barometer Rding

28.825

Load

0 Thermal Eff.

Room Temperature

73°

Steam Consumption BHP hr

Thermodynamic Eff. 0.5508

Date

2-22-09.

Steam Consumption IHP hr.

Potential Eff.

Gages

{ LION GARDINER.
WADE W REECE.

No	Time	Steam Press Gage lbs/sq in	Steam Cal. Temp Deg F.	Steam Qual.	RPM	M. E. P.			I. H. P.			BHP	Mechanical Eff	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV	H.E.	C.E.	Total.				
1	3:35	100	284	9955	296	1.35	7.8	4.57	.8	4.45	5.25			0	
2	4:01	102	286	9958	304	1.70	7.6	4.69	1.18	4.46	5.24				
3	4:45	102	286	9958	301	1.76	8.8	5.28	1.07	5.12	6.19			134	
4	4:50	98	285	9962	302	1.75	8.8	5.28	1.05	5.14	6.19				
5	5:55	100	285	996	296	1.36	8.	4.68	.81	4.58	5.39			129.	
6	4:00	100	285	996	305	2.01	7.2	4.6	1.22	4.25	5.47				
7	4:05	100	284	9955	308	2.01	7.4	4.7	1.23	4.77	6.			131.5	
8	4:10	100	284	9955	307	1.86	7.8	4.63	.72	4.78	5.50				
9	4:15	102	284	995	309	1.58	7.2	4.39	.91	4.78	5.69			134.5	
10	4:20	102	284	995	302	1.41	8.2	4.8	.85	4.79	5.64				
11	4:25	102	284	995	307	2.14	8.	5.07	1.3	4.75	6.05			134	
12	4:30	98	284	9955	304	1.62	8.	4.81	.97	4.58	5.55				
13	4:35	100	284	9956	298	1.35	7.4	4.37	.8	4.26	5.06			132	
		100.47	284.5	9957							5.65			795.	

NOTE:- THIS IS FOR DEGREE OF BACHELOR OF SCIENCE.

UNIV. OF ILLINOIS. MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 100 Mechanical Eff. .7173 Barometer Rding 29.59
 Load $\frac{1}{4}$ Thermal Eff. .0245 Room Temperature 67°
 Steam Consumption BHP hr 87.25 Thermodynamic Eff. .097 Date 2-25-09.
 Steam Consumption I.H.P. hr. 62.38 Potential Eff. .0692 Names { LION GARDINER.
 WADE W REECE.

No	Time.	Steam Press Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			BHP	Mech Eff	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
3	1:40	103	286	9962	300	16.4	19.2	17.8	9.77	11.12	20.89	15	.718	0	
4	1:45	100	286	9963	302	16.4	19.2	17.8	9.82	11.3	21.12	15.1	.745		
5	1:50	101	286	996	298	14.5	20.9	17.2	8.6	12.08	20.68	14.9	.72	209.5	
6	1:55	101	286	996	300	16.4	19.6	18.5	9.77	11.35	21.12	15	.71		
7	2:00	100	281	995	298	14.4	18.5	16.4	8.53	10.7	19.23	14.9	.715	228.8	
8	2:05	100	284	9945	300	18	22	20	10.71	12.8	23.51	15	.64		
9	2:10	100	285	9955	298	16.8	19	17.4	9.95	10.95	20.9	14.9	.715	217	
10	2:15	98	283	9952	301	17.2	18	17.6	10.3	10.5	20.8	15.05	.725		
11	2:20	103	283	9945	299	17.4	19.6	18.5	10.31	11.35	21.66	14.95	.69	221.5	
12	2:25	103	282	9944	301	15.6	16.9	16.3	9.32	10.15	19.47	15.05	.775		
13	2:30	102	284	995	299	17.2	19.7	18.4	10.2	11.4	21.6	14.95	.692	212.2	
14	2:35	101	284	9952	296	18.9	18.8	18.8	11.15	10.75	21.8	14.8	.68		
15	2:40	100	283	995	296	15.6	18.8	17.2	9.17	10.75	19.92	14.8	.74	213	
AVG		100.9		9953							20.98	14.95	.717	1301.8	

NOTE:- THESIS FOR DEGREE OF BACHELOR OF SCIENCE.

UNIV. OF ILLINOIS. MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 100 Mechanical Eff. .879 Barometer Rding 29.275

Load $\frac{1}{2}$ Thermal Eff. .0365 Room Temperature 67°

Steam Consumption BHP hr 59.1 Thermodynamic Eff. .125 Date 2-25-09.

Steam Consumption IHP hr 51.8 Potential Eff. .11 Names { LION GARDINER.
WADE W REECE.

No	Time	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg F.	Steam Qual.	RPM	M. E. P.			I. H. P.			B.H.P.	Mech. Eff	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
1	2:45	102	281	9945	300	30.	28	29.	17.85	16.25	34.1	30.	.88	0	
2	3:00	103	285	9953	298	28.4	27.3	27.8	17.7	15.75	33.45	29.8	.89		
3	3:15	104	287	996	296	28.15	29.	28.5	16.54	16.61	33.15	29.6	.895	292.75	
4	3:30	100	287	9947	295	26.17	30.	27.2	15.3	17.14	32.44	29.5	.91		
5	3:45	100	286	9943	300	27.36	28.15	27.7	16.27	16.32	32.59	30.	.921	302.25	
6	4:00	100	286	9943	299	30.92	28.4	29.6	18.35	16.42	34.77	29.9	.86		
7	4:15	100	285	9944	297	29.2	27.6	28.4	17.2	15.87	33.07	29.7	.90	288.25	
8	4:30	102	287	9944	297	28.	29.59	28.8	16.35	17.15	33.5	29.7	.887		
9	4:45	100	286	9943	296	28.8	29.59	29.2	16.9	16.93	33.83	29.6	.875	288.75	
10	5:00	100	282	9943	296	30.	29.57	25.8	17.61	16.93	34.54	29.6	.86		
11	5:15	97	285	996	298	29.2	30.	29.6	17.27	17.31	34.58	29.8	.862	286.5	
12	5:30	99	285	9961	296	29.2	29.35	29.3	17.13	16.8	33.93	29.6	.875		
13	5:45	100	284	996	298	30	29.	29.5	17.75	16.71	34.46	29.8	.865	295	
AVG		100.5		9949							33.88	29.73	.879	1753.5	

NOTE:- THESIS FOR DEGREE OF BACHELOR OF SCIENCE.

UNIV. OF ILLINOIS. MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 100 Mechanical Eff. .911 Barometer Rdg. 29.676

Load $\frac{3}{4}$ Thermal Eff. .0445 Room Temperature 62.°

Steam Consumption BHP hr 48.4 Thermodynamic Eff. .159 Date 2-25-09

Steam Consumption IHP hr 44. Potential Eff. .145 Names { LION GARDINER.
WADE W REECE.

No	Time.	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			BHP	Mech. Steam Eff	Flow Lbs.	Remarks
						H.E.	C.E.	AV	H.E.	C.E.	Total.				
1	8:55	100	288	9977	295	44.	42.	43.	25.78	27.	49.78	44.3	.89	0	
2	9:00	100	288	9977	294	42.7	41.6	42.1	24.98	23.63	48.61	44.1	.91		
3	1:05	100	286	9975	295	42.1	41.	41.5	24.63	23.4	48.03	44.3	.918	35025	
4	1:10	100	287	9946	295	45.1	40.8	42.9	26.4	23.35	49.75	44.3	.89		
5	1:15	100	287	9946	295	40.	38.	39.	23.4	21.67	45.07	44.3	.98	36875	
6	1:20	100	287	9943	296	41.85	41.6	41.7	24.59	23.81	48.4	44.4	.916		
7	1:25	100	288	995	294	45.	41.7	43.3	26.25	23.69	49.94	44.1	.885	35725	
8	1:30	100	288	9977	297	42.	40.95	41.5	24.78	23.5	48.28	44.5	.92		
9	1:35	99	286.5	9946	297	42.65	40.8	41.7	25.12	23.46	48.58	44.5	.915	356.5	
10	1:40	100	287	9946	298	41.9	40.6	41.2	24.79	23.4	48.19	44.7	.92.5		
11	1:45	101	287	9945	295	44.4	40.	42.2	26.	22.82	48.82	44.3	.906	356	
12	1:50	100	287	9946	298	41.8	40.	40.9	24.72	23.95	48.8	44.8	.92		
13	1:55	100	286.5	9944	297	44.	44.2	44.1	25.98	25.4	51.38	44.7	.87	355	
AVG		100	287.5	9955							48.73	44.4	.911	2144	

NOTE: THESIS FOR DEGREE OF BACHELOR OF SCIENCE.

UNIV. OF ILLINOIS MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure

115 Mechanical Eff.

Barometer Rding

2907

Load

0 Thermal Eff.

Room Temperature 72°

Steam Consumption BHP Hr.

Thermodynamic Eff. 0.481 Date

2-20-'09.

Steam Consumption H.P. Hr.

128 Potential Eff.

Notes {

LIGN VARDINER.

WADE W RLEGE.

No	Time	Steam Press Gage lbs/sq.in	Cal. Temp Deg F.	Steam Qual.	RPM	M. E. P.			I. H. P.			BHP	Mech Eff	Remarks
						H.E.	C.E.	AV	H.E.	C.E.	Total			
5	1:30	116.	291.5	9965	297	1.36	10.	5.68	.8	5.75	6.55			0
6	1:35	114.5	291.5	9965	295	2.8	10.	6.4	1.66	5.71	7.37			
7	1:40	113.	290.5	9964	295	1.36	9.76	5.56	.796	5.57	6.37			157
8	1:45	115.	290.5	996	297	3.76	10.55	7.15	2.121	6.06	8.18			
9	1:50	114.	289.5	9955	297	1.2	9.36	5.28	.707	5.38	6.087			145.
10	1:55	115.	289.5	9952	292	1.04	9.2	5.12	.605	5.21	5.82			
11	2:00	116.	289.5	995	302	.80	12.0	6.4	.48	7.01	7.49			146.
12	2:05	115.5	285.	9935	302	1.2	9.6	5.4	.719	5.62	6.34			
13	2:10	113.5	286.5	994	300	1.6	8.8	5.2	.952	5.11	6.06			146.
14	2:15	112.5	285.	9938	294	1.2	9.6	5.3	.7	5.46	6.16			
15	2:20	114.5	285.	9935	300	1.76	10.4	6.07	1.05	6.04	7.09			144.
16	2:25	115.	283.	992	300	.80	8.8	4.8	.466	5.11	5.58			
17	2:30	114.	283.	9924	294	2.0	8.8	5.4	1.165	5.0	6.16			143.
AVG		114.5		9948										881.

NOTES: THESE FOR DEGREE OF BACHELOR OF SCIENCE.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 115 Mechanical Eff. .704 Barometer Rding. 29.075
 Load 1/4 Thermal Eff. .025 Room Temperature 70°

Steam Consumption BHP hr 864 Thermodynamic Eff. .0996 Date

2-20-'09.

Steam Consumption IHP hr. 60.78 Potential Eff. .0702 Names { LION GARDINER.
 WADE W REECE.

No	Time.	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			B H P	Mech. Eff.	Steam Flow. Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
3	3:00	112.5	280.5	99.65	297	16.0	22.58	19.29	9.41	12.98	22.39	14.85	.664	0	
4	4:05	115	289.5	99.52	297	14.0	22.0	18.0	8.25	12.14	20.39	14.85	.729		
5	5:10	115	289.5	99.15	306	13.6	22.5	18.05	8.25	13.3	21.55	15.3	.71	212.	
6	6:15	115	289.5	99.52	296	12.16	20.0	16.08	7.15	11.45	18.6	14.8	.796		
7	7:20	115	289.	99.51	297	12.8	22.0	17.4	7.65	12.65	20.2	14.85	.735	211	
8	8:25	115	286.5	99.4	300	14.4	22.0	18.2	8.9	12.78	21.68	15.0	.692		
9	9:30	116	285.5	99.3	294	14.8	22.0	18.4	8.65	12.51	21.16	14.7	.722	212.	
10	10:35	116	286	99.31	299	15.2	22.0	18.6	9.02	12.7	20.72	14.95	.688		
11	11:40	112.5	286.5	99.45	290	15.2	22.0	18.6	8.75	12.32	21.07	14.5	.656	216	
12	12:45	120.	285.	99.22	297	16.8	22.99	19.39	9.92	12.72	22.64	14.85	.688		
13	1:50	114.5	287.	99.42	296	15.2	22.0	18.6	8.97	12.6	21.57	14.8	.668	218	
14	3:55	114.5	288.	99.5	298	15.8	22.6	19.2	9.36	12.95	22.31	14.9	.706		
15	4:00	115.0	288.	99.45	298	14.9	22.43	18.66	8.24	12.87	21.11	14.9	.705	214.	
AV.		115.08		99.5							21.85	14.86	.704	228.3.	

UNIV. OF ILLINOIS MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 115 Mechanical Eff. .8472 Barometer Rding 29.08

Load $\frac{1}{2}$ Thermal Eff. .0363 Room Temperature 69.5°

Steam Consumption BHP hr 59.4 Thermodynamic Eff. .129 Date 2-20-09.

Steam Consumption IHP hr 50.38 Potential Eff. .109 Names {

{ LION GARDINER.
WADE W REECE.

No	Time	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual. RPM	M. E. P.			I. H. P.			B.H.P.	Mech. Steam Eff	Flow Lbs.	Remarks
					H.E.	C.E.	AV	H.E.	C.E.	Total.				
1	4:10	115	289.5	995.2	29.3	32.1	33.05	18.7	19.3	37.0	29.3	.784	0	
2	:15	115	288	994.5	29.6	27.6	28.8	16.2	17.1	33.38	29.6	.888		
3	:20	115	289.5	995.2	29.7	27.6	28.8	16.2	17.2	33.50	29.7	.887	29%	
4	:25	116	290.5	995.5	29.7	28.4	30.4	16.7	17.9	34.62	29.7	.858		
5	:30	114	290.5	996	29.6	30.4	31.2	17.8	18.3	36.16	29.6	.82	296	
6	:35	115	289.5	995.2	29.6	29	29.7	17.0	17.4	34.46	29.6	.859		
7	:40	114	288	995	29.7	30	31.2	17.6	17.9	35.59	29.7	.836	298	
8	:45	114	287.0	994.3	29.8	31.4	31.75	18.6	18.3	36.9	29.8	.808		
9	:50	116	286	993.5	29.7	29.0	29.8	17.1	17.6	34.73	29.7	.856	393	
10	:55	115	287	994.5	29.5	29.0	29.5	17.0	17.1	34.12	29.5	.865		
11	5:00	115	288	994.5	29.6	30.2	30.3	17.7	17.4	35.12	29.6	.843	293,	
12	:05	114	288	995	29.5	27.6	29.8	17.3	17.2	34.44	29.5	.856		
13	:10	114	288	995	29.7	30.0	30.1	17.6	17.2	35.4	29.7	.84	294.	
AV		114.77		994.9						35.03	29.75	.847	1765.	

UNIV. OF ILLINOIS. MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 115 Mechanical Eff. .88 Barometer Rding 29.251

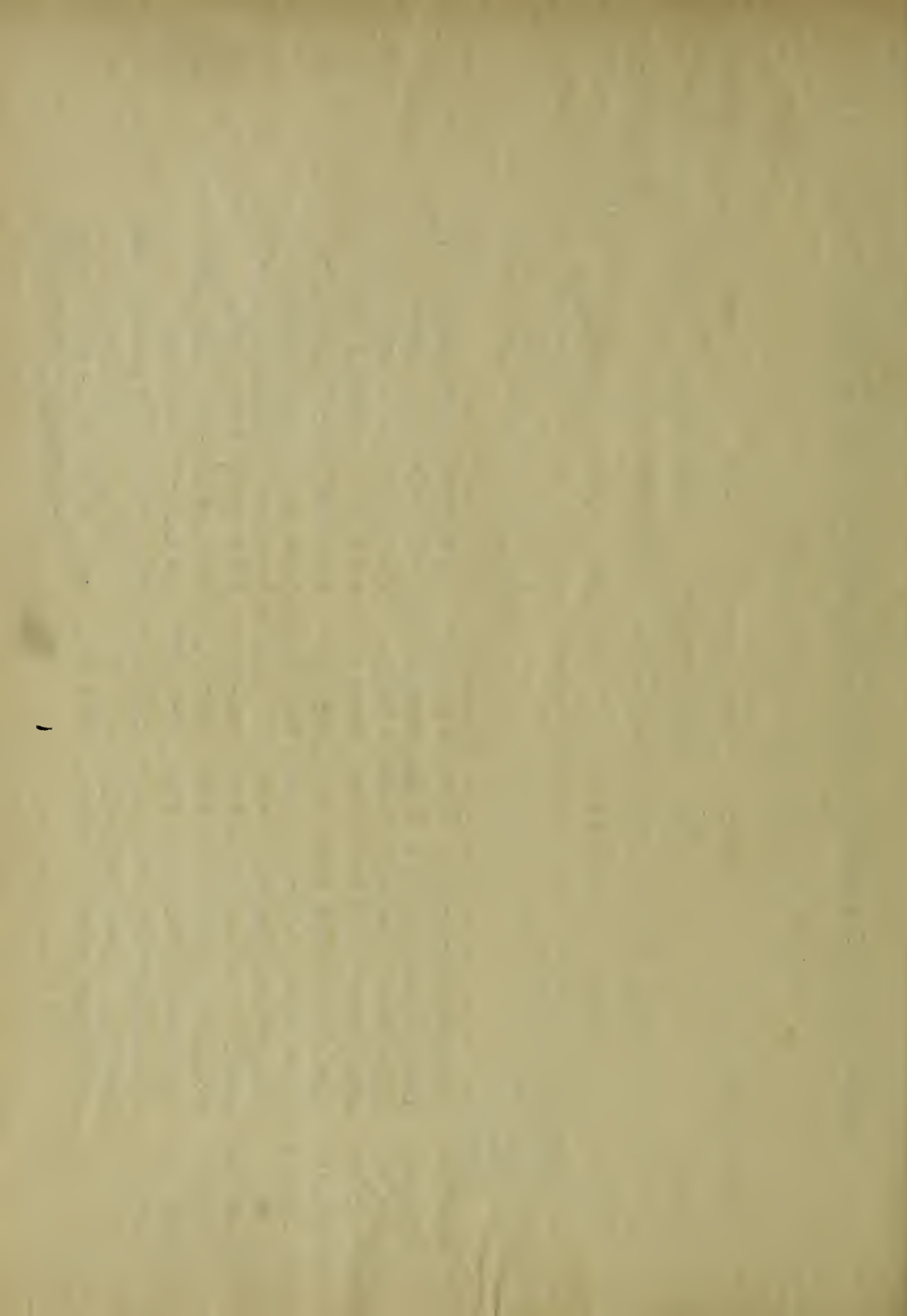
Load 3/4 Thermal Eff. .0412 Room Temperature 71.5°

Steam Consumption BHP hr 51.23 Thermodynamic Eff. .155 Date 2-22-09

Steam Consumption I.H.P hr 45.1 Potential Eff. .137 Names { LION GARDINER.
WADE W REECE.

No	Time	Steam Press Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.		B.H.P.	Mech. Eff	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.				
1	4:15	114	291.5	9965	302	44	43.6	43.8	26.4	25.4	51.8	45.3	.875	0
2	4:20	115	291.5	9965	300	46.6	44.3	45.45	27.8	25.7	53.5	45	.841	
3	4:25	115	292.5	9975	296	44.4	44.3	44.35	26.1	25.4	52.5	44.4	.845	381
4	4:30	115	292.5	9975	299	43.2	44.5	43.85	25.6	25.9	51.5	44.85	.872	
5	4:35	115	292.5	9975	298	40.9	42.8	41.85	24.3	24.65	48.95	44.75	.915	370
6	4:40	115	291.5	9965	297	43.6	43.2	43.4	25.7	24.8	50.5	44.55	.883	
7	4:45	115	292.5	9935	295	42.4	43.1	42.75	24.8	24.6	49.4	44.25	.897	382
8	4:50	115	292.5	9975	296	42.0	43.6	42.8	24.7	24.9	49.6	44.4	.895	
9	4:55	115	292.5	9975	293	45.6	45.4	45.5	26.8	25.7	51.2	44.0	.86	383
10	5:00	115	292.5	9975	300	43.2	42.8	43.0	25.2	24.8	50	45	.90	
11	5:05	117	292.5	9968	296	43.2	42.0	42.6	25.4	24.1	49.5	44.4	.898	389
12	5:10	116	292.5	997	300	44.2	42.2	42.2	26.2	24.4	50.6	45.0	.889	
13	5:15	116	292.5	997	297	42.8	45.2	44.0	25.2	26.0	51.2	44.55	.87	379
AV		115.23		9972							50.78	44.65	.88	2284

NOTE:- THESIS FOR DEGREE OF BACHELOR OF SCIENCE.



UNIV. OF ILLINOIS. MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 130 Mechanical Eff. Barometer Rding. 29.141
 Load 0 Thermal Eff. Room Temperature 64°
 Steam Consumption BHP hr. Thermodynamic Eff. .0538 Date 3-20 '09.
 Steam Consumption I.H.P. hr. 111 lbs. Potential Eff. Names { LION GARDINER.
 WADE W REECE.

No	Time.	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM.	M. E. P.			I. H. P.			B.H.P.	Mech. Eff.	Steam Flow. Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
1	1.35	130.7	293.5	99.48	300	3.00	9.35	6.18	1.89	5.43	7.22			0	
2	.40	130.7	294.5	99.52	298	3.00	9.05	6.01	1.78	5.21	6.99				
3	.45	130.7	294.5	99.57	300	3.02	9.02	6.02	1.79	5.26	7.05			147	
4	.50	131.7	295.5	99.52	298	3.02	9.05	6.03	1.78	5.21	6.99				
5	.55	130.7	294.5	99.48	299	3.62	9.95	6.80	2.15	5.76	7.91			145.8	
6	2.00	130.7	293.5	99.48	297	3.02	9.05	6.03	1.78	5.20	6.98				
7	.05	130.7	293.5	99.52	298	3.62	11.10	7.30	2.15	5.21	7.36			145.8	
8	.10	130.7	294.5	99.52	298	3.02	10.87	6.99	1.78	6.40	8.18				
9	.15	130.7	295.5	99.58	297	3.02	8.75	5.88	1.78	6.52	8.30			155.0	
10	.20	130.7	295.5	99.58	300	3.62	9.35	6.48	2.15	5.08	7.23				
11	.25	130.7	293.5	99.48	300	2.4	9.35	5.87	1.43	5.43	6.86			140.	
12	.30	130.7	293.5	99.48	300	3.02	9.05	6.03	1.78	5.06	6.84				
13	.35	130.7	293.5	99.48	298	2.40	8.68	5.54	2.40	5.01	7.41			140.	
Av.		130.78	294.27	99.514							7.33			873.6	

NOTE:- THESIS FOR DEGREE OF BACHELOR OF SCIENCE.

UNIV. OF ILLINOIS. MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 130 Mechanical Eff. .666 Barometer Rding 29.314
 Load $\frac{1}{4}$ Thermal Eff. .023 Room Temperature 68°
 Steam Consumption BHP hr 92.1 Thermodynamic Eff. .098 Date 3-13, '09.
 Steam Consumption I.H.P. hr. 61.2 Potential Eff. .064 Names { LION GARDINER
 WADE W REECE.

No	Time	Steam Press Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			B.H.P.	Mech. Eff.	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
1	1:30	129.0	291.5	99.42	306	12.06	23.17	17.6	7.31	13.68	20.99	15.30	.730	0	
2	.35	130.7	293.5	99.47	303	13.26	25.59	19.4	7.96	14.99	22.95	15.15	.665		
3	.40	132.8	293.5	99.48	300	12.65	24.12	18.4	7.53	14.00	21.53	15.00	.700	221.5	
4	.45	131.7	293.5	99.49	300	13.26	23.17	18.1	7.79	13.42	21.21	15.00	.705		
5	.50	132.8	293.5	99.48	301	13.87	24.37	19.1	8.28	14.17	22.45	15.05	.667	230.5	
6	.55	132.8	294.5	99.50	298	12.65	24.12	18.5	7.50	13.90	21.40	14.90	.697		
7	2:00	130.7	293.5	99.50	302	15.07	25.35	20.1	9.03	14.78	23.81	15.10	.635	237.0	
8	.05	130.7	293.5	99.50	300	13.30	22.90	18.2	8.03	13.30	21.33	15.00	.705		
9	.10	131.7	293.5	99.48	300	15.68	24.12	19.9	9.33	14.00	23.33	15.00	.645	233.7	
10	.15	132.8	293.5	99.48	303	16.89	24.70	20.8	10.14	14.49	24.63	15.15	.615		
11	.20	130.7	292.5	99.42	302	15.68	23.50	19.5	9.38	13.72	23.10	15.10	.652	232.3	
12	.25	130.7	292.5	99.42	299	15.37	24.12	19.3	9.12	13.91	23.03	14.95	.650		
13	.30	129.5	291.5	99.38	302	16.89	24.70	20.8	10.13	14.41	24.54	15.10	.617	230.3	
Av.		131.3	293.12	99.46							22.64	15.06	.666	1385.3	

45

UNIV. OF ILLINOIS MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure

130

Mechanical Eff.

.854

Barometer Rding

29.181

Load

$\frac{3}{4}$

Thermal Eff

.042

Room Temperature

64°

Steam Consumption BHP hr

51.75

Thermodynamic Eff

.158

Date

4-3. '09,

Steam Consumption IHP hr

44.20

Potential Eff.

.135

Names

{ LION GARDNER,
WADE W RLEE.

No	Time	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg F.	Steam Qual.	RPM	M. E. P.			I. H. P.			BHP	Mech Steam Eff	Flow Lbs.	Remarks
						HE	CE	AV	HE	CE	Total				
1	8.50	132.8	291.3	99.35	298	49.4	43.4	46.4	29.17	25.59	54.76	44.7	81.5	0	
2	.55	129.5	292.4	99.42	298	44.6	43.6	44.1	26.35	25.18	51.43	44.7	87.0		
3	9.00	130.7	294.4	99.52	299	46.6	43.4	45.0	27.62	25.15	52.77	44.8	85.0	381	
4	.05	133.9	295.4	99.51	297	43.1	42.2	42.7	25.38	24.45	49.83	44.6	89.5		
5	.10	132.8	295.4	99.52	299	49.4	43.6	46.5	29.26	25.25	54.51	44.8	82.0	382	
6	.15	130.7	294.4	99.52	300	41.0	44.3	42.7	24.40	25.70	50.10	45.0	89.7		
7	.20	131.7	295.4	99.53	298	42.3	42.0	42.2	27.91	24.18	52.09	44.7	85.8	394	
8	.25	132.8	296.5	99.52	300	48.8	41.2	45.0	29.00	23.95	52.95	45.0	85.0		
9	.30	130.7	296.5	99.58	298	47.3	42.2	44.8	28.10	24.48	52.58	45.0	85.5	382.5	
10	.35	129.5	296.5	99.60	300	46.6	43.4	45.0	27.53	25.59	53.12	44.7	84.1		
11	.40	131.7	296.5	99.58	298	46.6	43.6	45.1	27.53	25.18	52.71	44.7	85.0	388	
12	.50	130.7	296.5	99.58	297	47.8	43.0	45.4	28.20	24.70	52.90	44.6	84.5		
13	.55	130.7	295.4	99.58	300	45.2	43.4	44.3	26.92	25.20	52.12	45.0	86.1	390	
	Av.	131.4		99.52							52.45		85.4	2317.5	

UNIV. OF ILLINOIS MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 130 Mechanical Eff. .915 Barometer Reading 29.273

Load Full Thermal Eff. .0474 Room Temperature 72°

Steam Consumption BHP hr 45.23 Thermodynamic Eff. .1688 Date

3-16 '09.

Steam Consumption IHP hr 41.40 Potential Eff. .1541 Names { LION GARDINER.
WADE W REECE.

No	Time.	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual. RPM	M. E. P.			I. H. P.			BHP	Mech. Eff	Steam Flow Lbs.	Remarks
					H.E.	C.E.	AV	H.E.	C.E.	Total.				
1	2:10	130.7	295.5	29.55	56.9	54.9	55.9	33.65	31.62	65.27	59.6	.915	0	
2	15	130.7	294.5	29.52	56.9	53.1	55.0	33.40	30.86	63.26	58.8	.929		
3	20	131.7	294.5	29.52	56.3	53.0	54.6	33.10	34.00	67.10	59.2	.880	445	
4	25	132.8	295.5	29.53	57.3	53.2	55.3	33.85	30.62	63.47	59.6	.940		
5	30	130.7	295.5	29.55	56.1	54.3	55.2	32.80	31.00	63.80	59.0	.925	440	
6	35	130.7	293.5	29.47	56.7	54.9	55.8	32.90	31.15	64.05	58.6	.915		
7	40	131.7	294.5	29.50	56.7	54.3	55.5	33.30	31.00	64.30	59.2	.918	447	
8	45	130.7	295.5	29.55	63.0	54.3	58.6	35.40	31.00	66.40	59.2	.891		
9	50	130.7	294.5	29.55	57.0	54.3	55.7	33.60	31.00	64.60	59.0	.915	449	
10	55	130.7	294.5	29.51	58.5	53.3	55.9	34.00	30.20	64.20	58.6	.915		
11	3:00	132.8	294.5	29.50	56.1	54.7	55.4	32.80	32.60	65.40	59.0	.902	450	
12	10	129.0	295.5	29.53	57.5	52.1	54.8	33.61	29.80	63.41	59.0	.930		
13	10	129.0	293.5	29.50	62.0	56.6	59.3	35.10	32.60	67.70	59.0	.872	445	
AV		130.9	294.65	29.52						64.61	59.07	.915	2676	

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure

130

Mechanical Eff.

.93.5

Barometer Rding

29.26

Load

1 1/4

Thermal Eff.

.0503

Room Temperature

70°

Steam Consumption BHP hr

42.8

Thermodynamic Eff.

.1649

Date

3-16 '09.

Steam Consumption IHP hr

40.0

Potential Eff.

.1633

Names

{ LION GARDINER.
WADE W REECE.

No	Time.	Steam Press Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual. RPM	M. E. P.			I. H. P.			BHP	Mech. Eff	Steam Flow lbs.	Remarks
					H.E.	C.E.	AV.	H.E.	C.E.	Total.				
1	3.15	130.7	293.5	99.53	291	70.2	63.9	67.5	40.5	36.0	76.5	72.7	95.0	0
2		129.5	293.5	99.54	300	69.4	64.5	66.9	41.4	37.4	78.9	75.0	95.0	
3		130.7	293.5	99.53	295	71.1	65.1	68.1	41.6	37.1	78.7	73.7	93.5	530
4		131.7	294.5	99.58	297	71.7	66.9	69.3	42.3	37.8	80.1	74.2	86.4	
5		132.8	295.5	99.60	299	75.0	71.7	63.3	44.5	41.5	86.0	74.9	87.0	532
6		131.7	295.5	99.61	296	76.2	61.2	68.7	44.8	35.1	79.9	74.0	92.7	
7		130.7	294.5	99.58	296	69.9	62.7	66.3	39.3	35.9	75.2	74.0	98.0	525 Load dropped.
	Av	131.5	294.36	99.56						79.3	74.07	93.5	1587	

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure

140

Mechanical Eff.

Barometer Rding

29.13

Load

0

Thermal Eff.

0355

Room Temperature

68°

Steam Consumption BHP hr

Thermodynamic Eff.

Date

3-20-09.

Steam Consumption IHP hr

168

Potential Eff.

Names

LION GARDINER.

WADE W REECE.

No	Time.	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			BHP	Mech. Eff.	Steam Flow. Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
1	2:55	140.3	293.5	99.26	298	3.06	8.75	5.9	1.81	5.02	6.83				
2	3:00	139.4	293.5	99.3	296	2.95	8.75	5.85	1.73	5.	6.73			162.5	
3	3:05	137.3	293.5	99.38	298	3.06	9.35	6.2	1.8	4.45	6.25			~~161.3~~	
4	3:10	138.5	295.5	99.42	300	3.32	10.4	6.86	1.64	4.94	6.58			161.3	
5	3:15	140.3	294.5	99.38	299	3.06	9.35	6.2	1.82	4.48	6.30				
6	3:20	140.3	294.5	99.38	300	3.32	9.35	6.32	1.64	4.48	6.12			169.	
7	3:25	136.7	293.5	99.4	300	3.06	9.05	6.05	1.82	4.36	6.18				
8	3:30	139.4	293.5	99.3	298	2.9	9.35	6.12	1.46	4.47	5.93			160.8	
9	3:35	140.3	293.5	99.26	300	3.06	9.95	6.5	1.81	4.78	6.60				
10	3:40	140.3	293.5	99.26	298	3.06	9.95	6.5	1.84	4.75	6.76			166.7	
11	3:45	140.3	297.5	99.4	300	3.26	8.75	6.0	1.94	5.07	7.01				
12	3:50	140.3	297.5	99.5	300	3.62	9.35	6.48	2.16	4.50	6.66			170.5	
13	3:55	140.3	297.5	99.5	300	3.06	9.65	6.35	1.82	4.64	6.46				
4:00	AV.	139.15	294.6	AV. 99.36							AV. 6.49			Total	1090.8

UNIV. OF ILLINOIS. MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure

140

Mechanical Eff.

.69

Barometer Rding

29.076

Load

1/4

Thermal Eff.

.023

Room Temperature 68°

Steam Consumption BHP hr 93.1 Thermodynamic Eff. 0.641 Date

3-20-09.

Steam Consumption I.H.P. hr. 64. Potential Eff. 0.934 Names

{ LION GARDINER.
WADE W REECE.

No	Time.	Steam Press Gage lbs/sq.in	Cal. Temp. Deg F.	Steam Qual.	RPM	M. E. P.			I. H. P.			BHP	Mech Eff	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
1	3:05	138	297.5	9953	305	13.05	22.	17.5	7.9	13.	20.9	15.25	.73		
2	3:10	139	297.5	9952	304	15.9	24.	19.95	9.6	14.1	23.7	15.2	.64		
3	3:15	140	297.5	9951	303	12.7	23.5	18.1	7.65	13.3	20.95	15.15	.725	230	
4	3:20	139	297.5	9952	304	12.	24.	18.0	7.25	14.	21.25	15.2	.712		
5	3:25	137	295.5	9948	302	12.7	23.5	18.1	7.62	13.7	21.32	15.1	.71	232	
6	3:30	139	295.5	9947	310	12.	24.	18.0	7.38	14.4	21.78	15.5	.715		
7	3:35	132	297.5	995	300	14.5	24.	19.25	8.15	13.9	22.65	15.	.663	239.5	
8	3:40	140	298.5	9957	308	11.45	24.7	18.07	7.0	14.7	21.7	15.4	.71		
9	3:45	140	296.5	9949	310	13.	22.	17.5	8.	13.2	21.2	15.5	.732	240	
10	3:50	140	296.5	9949	300	14.45	26.	20.22	8.62	15.1	23.72	15.	.643		
11	3:55	140	295.5	9942	302	12.	30.2	21.1	7.2	17.6	24.8	15.1	.61	231.	
12	4:00	141	296.5	9946	304	12.	25.3	18.6	7.25	14.4	21.65	15.2	.70		
13	4:05	141	296.5	9946	304	12.	25.6	18.8	7.25	15.1	22.35	15.2	.68	245	
AV.		139.7	296.7	9949							22.15	15.2	.69	1417.5	

NOTE: THESIS FOR DEGREE OF BACHELOR OF SCIENCE.

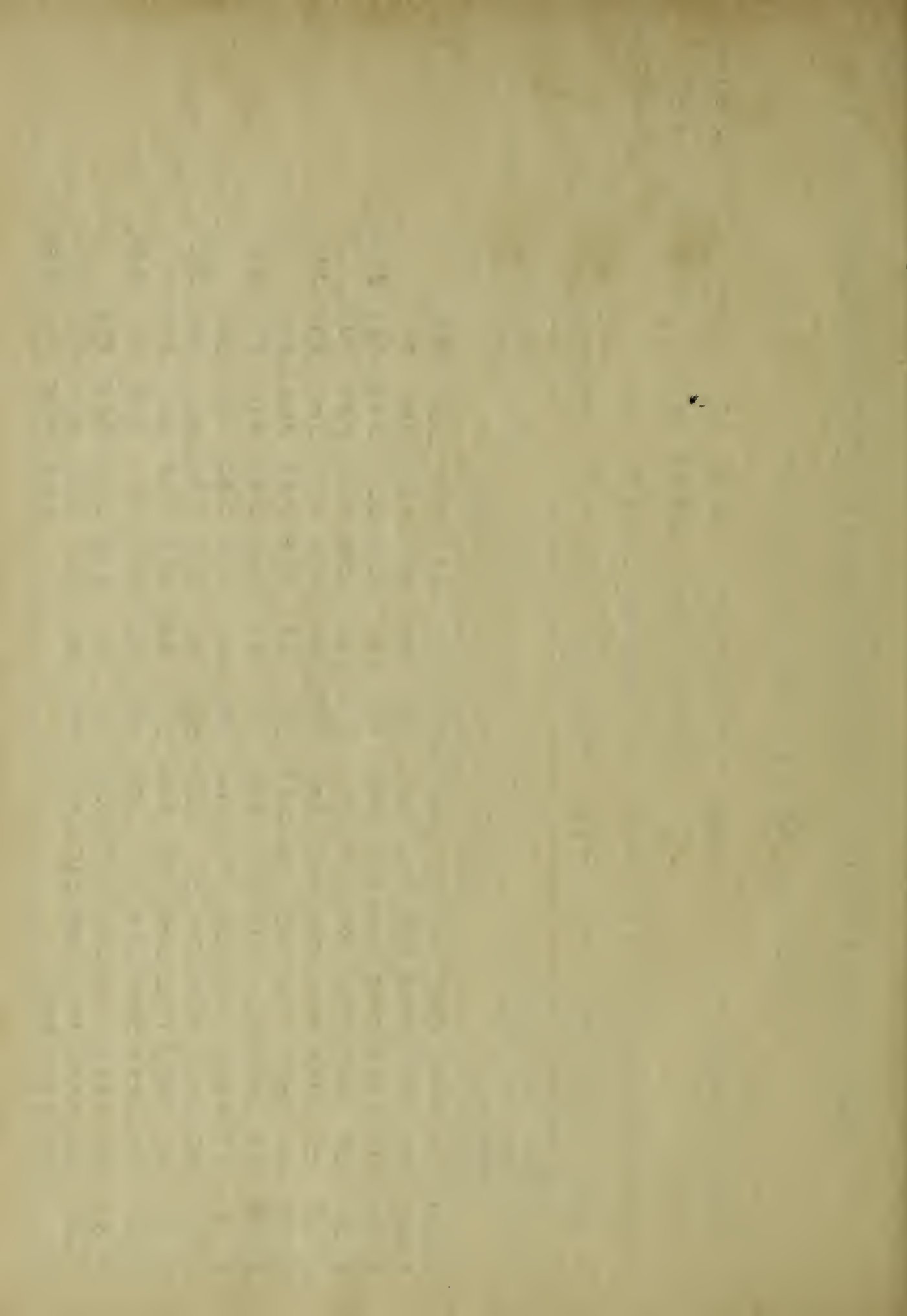
UNIV. OF ILLINOIS. MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 140 Mechanical Eff. .779 Barometer Rding 29.116
 Load 1/2 Thermal Eff. .0352 Room Temperature 68°
 Steam Consumption BHP hr 61.1 Thermodynamic Eff. 139 Date 3-20 '09.
 Steam Consumption I.H.P hr. 47.5 Potential Eff. .108 Names { LION GARDINER.
 WADE W REECE.

No	Time.	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			B.H.P.	Mech. Eff.	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
2	3:35	140	295.5	9942	303	27.1	38.78	32.9	16.2	22.1	38.4	30.3	.789		
3	40	140	295.5	9948	304	30.2	41.2	35.7	18.2	24.2	42.4	30.4	.72		
4	45	139	295.5	9942	306	31.6	35.4	33.5	19.2	20.9	39.1	30.6	.783	306	
5	50	138	295.5	9945	306	33.4	36.2	34.8	20.2	21.4	41.6	30.6	.735		
6	55	141	295.5	9941	306	30.2	39.2	34.7	18.7	23.2	41.9	30.6	.73	315	
7	4:00	140	295.5	9942	305	27.8	36.4	32.1	16.8	21.4	38.2	30.5	.80		
8	05	139	296.5	995	306	30.2	39.0	34.6	18.7	20.7	39.4	30.6	.776	320	
9	10	139	295.5	9945	304	27.8	36.2	32	16.8	21.2	38.0	30.4	.80		
10	15	138	295.5	9948	304	29	36.2	32.6	17.5	21.3	38.8	30.4	.784	305	
11	20	139	295.5	9945	304	27.2	35.6	31.4	16.4	21.9	37.3	30.4	.815		
12	25	139	295.5	9942	304	28.6	38.6	33.6	17.3	22.7	40	30.4	.76	304	
13	30	140	295.5	9941	302	26.8	35.6	31.2	16.1	20.8	36.9	30.2	.815		
14	35	142	295.5	9941	304	27.8	35.9	31.8	16.8	21.1	37.9	30.4	.801	310	
AV.		139.6	295.7	9944							39.2	30.45	.779	1860	

NOTE:- THESIS FOR DEGREE OF BACHELOR OF SCIENCE.



UNIV. OF ILLINOIS. MECHANICAL ENGINEERING LAB'Y.

TEST OF 60 H.P. IDEAL STEAM ENGINE.

Steam Pressure 140 Mechanical Eff. .875 Barometer Rding 29.22
 Load 3/4 Thermal Eff. .0433 Room Temperature 60°
 Steam Consumption BHP hr 48.6 Thermodynamic Eff. 163 Date 3-20.09
 Steam Consumption I.H.P. hr. 42.6 Potential Eff. 143 Names { LION GARDINER.
 WADE W REECE.

No	Time.	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			B.H.P.	Mech. Eff.	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
1	10:00	140.3	296.5	.9947	300	41.	41.	41.	24.7	24.	48.7	45.	.92		
2	10:05	140.3	296.	.9947	298	45.2	42.2	43.7	26.8	24.3	51.1	44.7	.875		
3	10:10	139.4	297.5	.9952	294	48.3	44.	46.7	28.2	25	53.2	44.1	.83	374	
4	10:15	140.3	297.5	.9952	292	44.0	45.2	44.6	25.5	25.6	51.1	43.8	.858		
5	10:20	138.5	297.5	.9952	294	43.5	38.	40.8	25.4	21.6	47.	44.1	.938	370	
6	10:25	140.3	296.	.9946	295	46.6	39.8	43.2	27.3	22.8	49.1	44.3	.90		
7	10:30	141.3	294.5	.9938	294	41.	43.	42.0	24.	24.5	48.5	44.1	.91	370	
8	10:35	140.3	294.5	.994	296	47.	46.6	46.8	27.6	26.7	54.3	44.4	.818		
9	10:40	140.3	293.5	.9937	294	48.2	45.2	46.7	28.	25.7	53.9	44.1	.91	369	
10	10:45	142.3	292.5	.9922	293	46.4	39.8	43.1	25.	22.6	47.6	44.	.925		
11	10:50	142.3	293.5	.993	296	46.	39.8	42.9	27.	22.8	49.8	44.4	.89	370	
12	10:55	139.4	293.	.9938	296	50.6	40.	45.3	29.6	22.9	52.5	44.4	.845		
13	11:00	140.3	290.5	.991	296	45.2	41.5	43.4	26.5	23.8	50.3	44.4	.882	376	
AVG		140.4	295.	.9939							50.6	44.3	.875	2159	

NOTE:- THESIS FOR DEGREE OF BACHELOR OF SCIENCE.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure

140.

Mechanical Eff.

.891

Barometer Rding.

29.214

Load

i.

Thermal Eff.

.05

Room Temperature

66°

Steam Consumption BHP hr

45.2

Thermodynamic Eff.

.173

Date

4-3. '09.

Steam Consumption IHP hr

40.3

Potential Eff.

.154

Names

{ LION GARDINER.
WADE W REECE.

No	Time.	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg F.	Steam Qual. RPM	M. E. P.			I. H. P.			B.H.P.	Mech. Steam Eff	Flow Lbs.	Remarks
					H.E.	C.E.	AV	H.E.	C.E.	Total.				
1	10.05	140.3	2924	9925	298	514	63.5	57.5	29.3	36.7	66	59.6	902	
2	10	141.3	2903	991	298	50	58.2	54.1	28.5	33.6	62.1	59.6	96	
3	15	140.3	2924	9925	298	61.5	54.3	57.9	36.4	31.4	67.8	59.6	88	442
4	20	140.3	2924	9925	300	64.2	57.4	60.8	38.2	33.4	71.6	60	84	
5	25	140.3	2924	9925	297	64	53.7	58.9	37.7	31	68.7	59.4	865	448
6	30	142.3	2904	9909	296	56.7	54.3	55.5	33.3	31.2	64.5	59.2	92	
7	35	140.3	2924	9925	298	58	56.4	57.2	34.3	32.6	66.9	59.6	89	455
AV		140.7		9921						66.8	59.5	891	1345	

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure

140

Mechanical Eff.

.884

Barometer Rding

29.25

Load

1 1/4

Thermal Eff.

.053

Room Temperature

66°

Steam Consumption BHP hr

42.75

Thermodynamic Eff

.185

Date

4-3-09

Steam Consumption IHP hr

37.8

Potential Eff.

.163

Names

{ LION GARDINER.
WADE W REECE.

No	Time	Steam Press. Gage lbs/sq.in	Cool. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			B.H.P.	Mech. Eff	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV	H.E.	C.E.	Total				
1	4:00	140.3	298.5	99.5	296	74.7	66.5	70.6	44.	38	82.	74.	905		
2	4:05	140.3	299.5	99.6	295	79.5	69.5	74.5	46.5	39.7	86.2	73.8	856		
3	4:10	142.3	299.5	99.6	298	71.7	78.5	75.1	42.7	45.5	88.2	74.5	845	531	
4	4:15	140.3	298.5	99.5	294	78.5	69.5	74.	45.8	39.6	85.4	73.5	86		
5	4:20	140.3	297.5	99.5	295	70.	69.5	69.7	41.	39.7	80.7	73.8	915	517	
6	4:25	141.3	298.5	99.5	296	70.	66.4	68.2	41.2	38.	79.2	74.	935		
7	4:30	140.3	298.5	99.5	298	71.4	74.8	73.1	42.1	43.1	85.2	74.5	876	535	
AV		140.7		99.56							83.9	74.1	884	1583	

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure

150

Mechanical Eff.

Barometer Rding

29.128

Load

0

Thermal Eff.

Room Temperature

58°

Steam Consumption BHP/hr

Thermodynamic Eff.

0.559

Date

3-20-'09

Steam Consumption IHP/hr

107.

Potential Eff.

Names

LION GARDINER.

WADE W REECE.

No	Time	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual. RPM	M. E. P.			I. H. P.			B.H.P.	Mech. Steam Eff	Flow Lbs.	Remarks
					H.E.	C.E.	AV	H.E.	C.E.	Total.				
1	4:10	151.1	297.5	9935	241	9.05	5.78	1.43	34	483				
2	4:15	150.1	298.5	994	3.62	8.44	6.04	2.14	486	7.00				
3	4:20	150.1	299.5	9945	3.62	7.84	5.87	2.14	452	6.66			178.5	
4	4:25	151.1	297.5	9942	3.64	8.54	6.09	2.16	4.9	7.06				
5	4:30	150.1	295.5	9925	2.55	8.74	5.65	1.52	5.09	6.61			174.5	
6	4:35	147.1	291.5	9905	3.62	8.14	5.88	2.13	4.67	6.8				
7	4:40	150.1	293.5	991	3.62	7.84	5.82	2.14	452	6.66			177.5	
8	4:45	149.2	294.5	992	2.41	9.05	5.78	1.44	5.25	6.69				
9	4:50	149.2	294.5	992	2.77	9.05	5.91	1.65	5.25	6.9			175.7	Boiler Press.
AV		149.5		9927						6.58			706.2	dropped and test was dis-
														continued.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 150 Mechanical Eff. .71 Barometer Rding 29.2504
 Load 1/4 Thermal Eff. .0203 Room Temperature 68°
 Steam Consumption BHP hr 104. Thermodynamic Eff. .0823 Date 4-3 '09.
 Steam Consumption I.H.P. hr 74 Potential Eff. .0585 Names { LION GARDINER.
 WADE W REEGE.

No	Time.	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			BHP	Mech. Eff.	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
1	12.05	150.1	297.3	.994	300	14.48	19.65	17.06	8.62	11.4	20.02	15	.733		
2	10	151.1	297.3	.9935	300	16.89	20.73	18.91	10.05	12.02	20.07	15	.68		
3	15	150.1	294.4	.9965	298	15.07	19.3	17.18	8.91	11.11	20.02	14.9	.738	261.8	
4	20	149.2	292.4	.991	298	15.68	20.12	18.40	9.26	11.60	20.86	14.9	.715		
5	25	150.1	292.4	.991	300	16.29	20.48	18.38	9.68	11.89	21.57	15	.698	263.4	
6	30	150.1	292.4	.991	297	15.91	21.32	18.61	9.39	12.24	21.63	14.9	.686		
7	35	149.2	290.3	.99	300	16.5	20.73	18.61	9.82	12.02	21.84	15	.686	259.5	
8	40	149.2	290.3	.989	298	14.48	19.52	17.	8.56	11.25	19.81	14.9	.752		
9	45	150.1	288.3	.989	300	16.5	19.3	18.4	9.82	11.2	21.02	15	.743	258.5	
10	50	150.1	288.3	.989	300	15.91	21.32	18.66	9.47	12.36	21.83	15	.686		
11	55	150.1	288.3	.989	297	14.92	21.7	18.31	8.8	12.47	21.27	14.9	.698	258	
12	1.00	150.1	290.3	.989	298	15.68	21.32	18.5	9.27	12.24	21.51	14.9	.694		
13	05	150.1	290.3	.991	299	16.29	19.1	17.69	9.67	11.03	20.7	14.95	.722	258	
AV.		149.8		.9914							21.1	14.95	.71	1559.2	

NOTE:- THESIS FOR DEGREE OF BACHELOR OF SCIENCE.

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure

150

Mechanical Eff.

.85

Barometer Rding

29.25

Load

1/2

Thermal Eff.

.0343

Room Temperature

65°

Steam Consumption BHP hr

64.5

Thermodynamic Eff.

.1118

Date

4-3-'09

Steam Consumption I.H.P hr.

54.7

Potential Eff.

.10

Names

LION GARDINER.

WADE W REECE.

No	Time.	Steam Press Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			BHP	Mech Eff.	Steam Flow Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
1	1:10	150.1	291.3	9905	299	30.16	31.	30.58	17.88	17.91	35.79	29.9	.837		
2	1:15	149.2	292.4	991	300	33.2	30.7	30.95	19.75	17.82	37.59	30.	.80		
3	1:20	149.2	291.3	9905	300	28.9	30.2	29.6	17.21	17.5	34.71	30.	.865	320.	
4	1:25	150.1	291.3	9905	298	28.9	30.2	29.6	17.19	17.5	34.69	29.8	.865		
5	1:30	150.1	291.3	9905	298	30.2	32.6	31.4	17.11	18.75	35.86	29.8	.832	313.5	
6	1:35	150.1	293.4	9915	297	28.9	29.8	29.4	17.18	17.11	34.29	29.7	.867		
7	1:40	146.2	291.3	991	296	30.2	28.8	29.5	17.09	16.6	33.69	29.6	.878	325.	
8	1:45	146.2	288.3	989	300	30.2	28.9	30.1	17.93	16.8	34.73	30.	.864		
9	1:50	149.2	288.3	989	298	30.2	32.6	31.4	17.8	18.75	36.55	29.8	.817	320.7	
10	1:55	150.1	291.3	9905	300	30.2	30.2	30.2	17.93	17.5	35.43	30.	.847		
11	2:00	150.1	292.4	9908	297	28.9	30.2	29.6	17.18	17.31	34.59	29.7	.86	361.3	Water measurement ran 1 min. over.
12	2:05	151.1	292.4	9905	299	28.9	29.2	29.1	17.19	16.9	34.09	29.9	.878		
13	2:10	150.1	292.4	9908	297	29.2	31.	30.1	17.31	17.91	35.22	29.7	.844	288	Ran 1 min. Under.
AV		149.3	292.4	9906							35.18	29.8	.85	1928	

TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 150 Mechanical Eff. . 9184 Barometer R'ing 29.25

Load $\frac{3}{4}$ Thermal Eff. . 044 Room Temperature 67°

Steam Consumption BHP hr 53.5 Thermodynamic Eff. . 141 Date 4-3 '09.

Steam Consumption I.H.P. hr 49.0 Potential Eff. . 129 Names { LION GARDINER.
WADE W REECE.

No	Time.	Steam Press. Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual.	RPM	M. E. P.			I. H. P.			BHP	Mech. Eff	Steam Flow. Lbs.	Remarks
						H.E.	C.E.	AV.	H.E.	C.E.	Total.				
1	2:15	148.2	291.3	9903	294	43.4	41.6	42.5	25.32	23.61	48.93	44.1	903		
2	20	150.1	291.3	9902	293	40.4	39.2	39.8	23.46	22.20	45.66	44	964		
3	25	150.1	293.4	991	292	42.5	42.5	42.5	24.59	23.99	48.58	43.85	903	392	
4	30	152.1	292.4	9905	294	43.4	41.6	42.5	25.32	23.61	48.93	44.1	903		
5	35	150.1	294.4	9912	296	40.5	42.5	41.75	24.3	24.05	48.35	44.1	918	394.5	
6	40	150.1	292.4	9905	294	42.5	40.4	41.95	24.78	22.98	47.76	44.1	923		
7	45	152.2	292.4	9905	294	43.4	40.4	41.9	25.32	22.98	48.3	44.1	914	396.	
8	50	150.1	294.4	9912	296	40.4	40.4	40.4	23.75	23.12	46.87	44.4	9475		
9	55	151.1	293.4	9908	295	41.0	41.6	41.3	23.65	23.4	47.05	44.3	9415	389.5	
10	00	149.2	294.4	9915	295	40.4	41.6	41.	23.6	23.75	47.35	44.3	937		
11	05	150.1	294.4	9912	294	45.2	40.4	42.8	26.39	22.98	49.37	44.1	895	384	
12	10	153.1	294.4	9910	292	45.2	42.4	43.8	26.18	23.96	50.14	43.85	875		
13	15	151.1	298.5	9935	292	42.2	41.6	41.9	24.41	23.5	47.91	43.85	9155	394.	
AV		150.6		991							48.1	44.1	9184	2350.	

NOTE:- THESIS FOR DEGREE OF BACHELOR OF SCIENCE

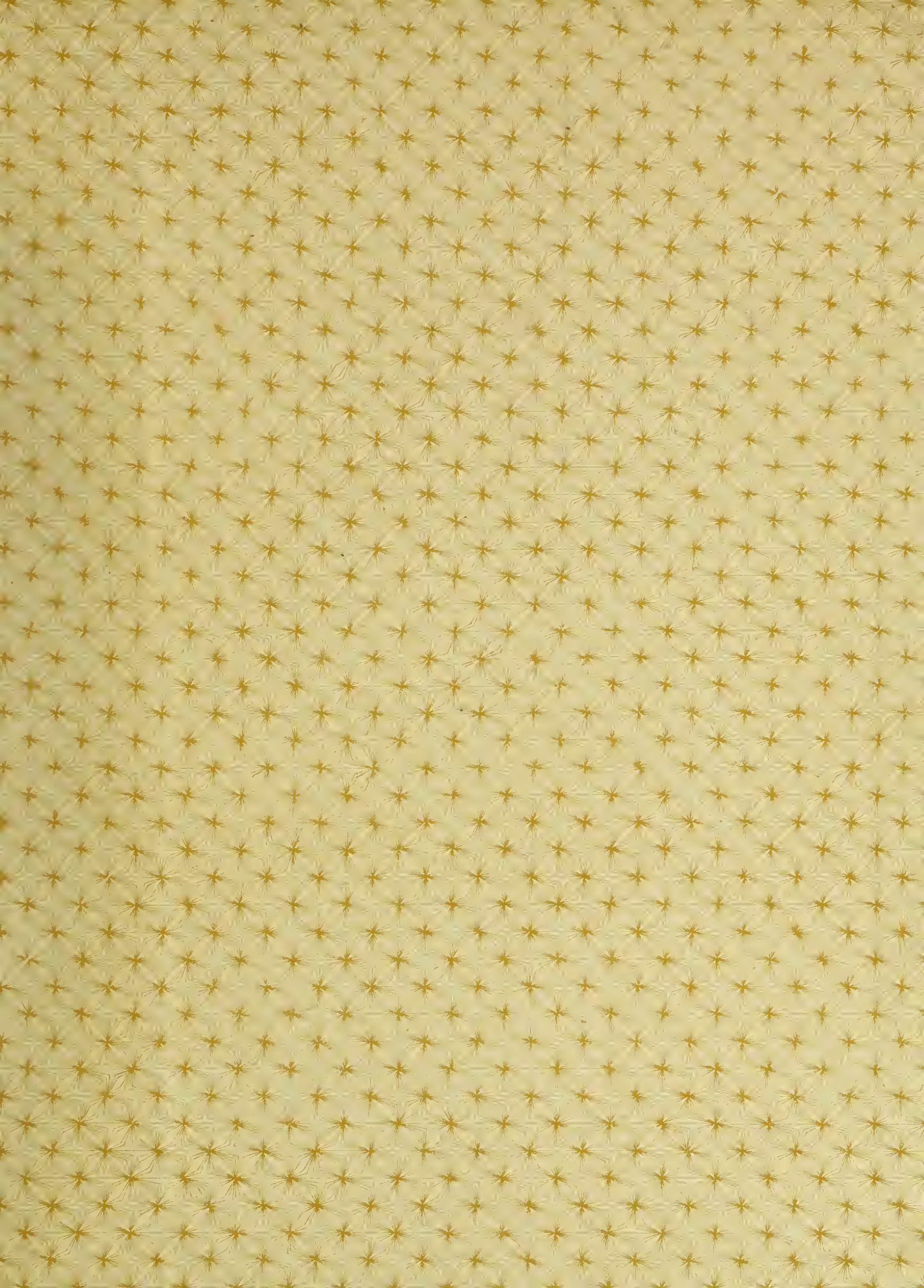
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TEST OF 60 H.P. IDEAL STEAM ENGINE

Steam Pressure 150 Mechanical Eff. .8766 Barometer Reading 29.25
 Load 1 Thermal Eff. .0484 Room Temperature 66°
 Steam Consumption BHP hr 48.5 Thermodynamic Eff. 1.638 Date 4-3, 09.
 Steam Consumption IHP hr 42.5 Potential Eff. .143 Names { LION GARDNER
 WADE W REECE

No	Time.	Steam Press Gage lbs/sq.in	Cal. Temp. Deg. F.	Steam Qual. RPM	M. E. P.			I. H. P.		BHP	Mech Steam Eff	Flow Lb.	Remarks
					H.E.	C.E.	AV	HE	C.E.				
1	3.20	1482	2985.994	294	62.7	54.9	63.8	37.4	31.2	68.6	58.85	858	
2	3.25	1472	2985.9942	292	55.65	52.8	54.22	32.8	30.0	62.8	58.4	.93	
3	3.30	1492	2995.995	297	55.65	54.3	54.87	33.3	31.2	64.5	59.4	.92	477
4	3.35	1472	2995.995	294	59.1	59.1	59.1	34.52	33.62	68.14	58.85	864	
5	3.40	1452	2995.9952	297	61.5	53.6	57.55	36.3	30.8	67.1	59.4	885	473.5
6	3.45	1452	2985.9945	294	65.7	53.3	59.5	38.3	32.	70.3	58.85	838	
7	3.50	1452	2985.9945	295	66.4	56.6	61.5	38.8	32.3	71.1	59.05	832	482
		1468	9945					67.5	59.	8766	1432	Ran 1/2 hr.	





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